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JOURNAL
OF THE
BOMBAY NATURAL HISTORY SOCIETY

DECEMBER 2009 VOL. 106 (3)

BNHS INDIA CONSERVING NATURE SINCE 1883

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ACKNOWLEDGEMENT

We are grateful to the Ministry of Science and Technology,
Govt of India,
for enhanced financial support for the publication of the Journal.

Editorial

Conserving Nature in a Globalizing India

As a part of its 125 year celebration, BNHS had organized an International Conference on 'Conserving Nature in a Globalizing India', at Bengaluru from February 17-19, 2009.

Most presentations at the conference were sharing of work experience and ideas, and discussions by experts, and therefore, could not materialize into peer-reviewed papers. Among those that were submitted as papers and accepted, after peer-review are published in this issue, along with the other articles accepted for the *JBNHS*.

To name a few: Simon N. Stuart, Chairman, IUCN Species Specialist Groups, discusses the extinction crises that our Earth is facing, mainly due to our activities. Sadly, one of the best examples of the extinction crisis is the Hangul or Kashmir Stag. Khursheed *et al.* have deduced that the last surviving and genetically viable Hangul population of 140-170 individuals is restricted to Dachigam National Park in Kashmir, making it one of the rarest mammals in the world. Emergency measures, besides conservation breeding, need to be taken to revive the population.

Despite the numerous benefits of biodiversity and healthy ecosystems to human being, Paul Morling has shown that biodiversity is still not a mainstream topic, and is undervalued and overexploited. It is very interesting, something we need so much that we over-exploit it, but at the same time we under-value it! Morling's paper reviews market-based approaches for identifying the salient features that determine their potential for improving conservation finance.

In this issue of the *JBNHS*, we also give extracts of some sessions: the discussion on Agriculture and Conservation, chaired by Dr. Rhys Green of Cambridge University and RSPB, and Mr. Ashish Kothari of Kalpavriksh, a famous NGO of India. The importance of community-based conservation was highlighted by Mr. Ashish Kothari and his team during an interactive session. Pankaj Sekhsaria discusses the impact of the tsunami of 2004 on Andaman and Nicobar Islands, and the aftermath of this unfortunate natural calamity. He emphasizes the importance of protection of the coastal zones, development planning, including tourism, and proper location of construction projects.

The importance of so-called 'wastelands' is highlighted by Dr. S.B. Munjpara and Dr. I.R. Gadhvi giving example of the Indian Courser, which is declining fast as its habitat is taken up by tree plantation, agricultural expansion, and industrial development. Like the Indian Courser, there are many species of short-grass plains of arid and semi-arid areas that are under threat as their habitat is generally outside the protected areas system.

Editors

FEB 23 2011

THE EXTINCTION CRISIS: FACT OR FICTION?

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The rapid disappearance of species is often referred to as one the world's greatest environmental concerns. The IUCN Red List of Threatened Species, which now includes more than 44,000 animal and plant species, shows that nearly one-quarter of the planet's 5,488 mammals and nearly one-third of the 6,255 amphibians are globally threatened or extinct. Similarly, worrying patterns of threat and decline have been found in other groups, such as birds, reef-building corals, and gymnosperms.

The IUCN Red List is the world's most comprehensive information source on the global conservation status of plant and animal species. Completed and ongoing assessments reveal the level of threat to species (highlighting those facing a high risk of global extinction) whilst also identifying the nature and distribution of major threats. Mapping the distribution of threatened species has identified that the proportion of threatened species differs markedly between groups and that the pattern of threat of one group does not predict the pattern of threat for another. The distribution of threatened species also shows very different patterns compared with depictions of overall diversity.

Numbers of threatened species are increasing across virtually all the major taxonomic groups. There are many drivers of species extinction, all arising either directly or indirectly from human activities. Overwhelmingly, the most common threat is habitat loss, but over-harvesting, incidental mortality, disease, pollution, and climate change are also major influences on the rate of species decline.

The Global Context

Biodiversity loss is one of the world's most pressing crises, with many species declining to critically low levels and with significant numbers going extinct. Biodiversity is essential for mankind because many a number of species, and the ecosystems they form, provide the vast array of goods and services that sustain our lives. However, despite the immense value of biodiversity, over the past 50 years humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history (Millennium Ecosystem Assessment 2005). This has resulted in a substantial and largely irreversible loss in the diversity of life on earth.

The structure and function of ecosystems have undergone unprecedented changes through the severe impacts of human activities. Land conversion, habitat change, pollution, overexploitation, invasive species and climate change are the direct drivers of threats that are compromising the continued provision of essential ecosystem services.

According to the Millennium Ecosystem Assessment (2005), since 1945, more land has been converted to cropland than in the 18th and 19th centuries combined. In the last several decades, 20% of the world's coral reefs were lost and a further 20% degraded; there has been a similar impact on mangrove areas — a 35% loss in the last several decades. The amount of water in reservoirs has quadrupled, and withdrawals from rivers and lakes have doubled since 1960. Transformations have also occurred across all of the world's biomes: between 1950 and 1990, 5-10% of the area of five biomes had been converted. By 1990, more than two thirds of the area of two biomes and more than half of the area of four others had been converted. (Millennium Ecosystem Assessment 2005).

Increasing human populations have a much greater collective impact on their surroundings particularly when their activities lead to excessive volumes of nutrients entering ecosystems. The flow of reactive nitrogen on the continents has already doubled, and some projections suggest that this may increase further by approximately two-thirds by 2050. Excessive nitrogen flows have severe environmental effects (eutrophication of freshwater and coastal ecosystems, contribution to acid rain, and loss of biodiversity), which contribute to creation of ground-level ozone, destruction of ozone in the stratosphere and global warming, all of which have subsequent adverse effects on human health (Millennium Ecosystem Assessment 2005).

By the end of the century, climate change and its impacts may be the dominant direct drivers of biodiversity loss and changes in ecosystem services globally. The balance of scientific evidence suggests that there will be a significant

Paper read at the International Conference on 'Conserving Nature in a Globalizing India' at Bengaluru; February 17-19, 2009

net harmful impact on ecosystem services worldwide, if global mean surface temperatures increase more than 2 °C above pre-industrial levels. This would require CO_2 stabilisation at less than 450 ppm (Millennium Ecosystem Assessment 2005).

The changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development. However, often these gains have been achieved at growing costs. Due to the degradation of many ecosystem services, levels of poverty have remained high, and inequities are growing. It is estimated that 1.1 billion people are surviving on an income of less than $1 per day, 70% of whom are in rural areas where they are highly dependent on ecosystem services (Millennium Ecosystem Assessment 2005).

Many people are still unable to access an improved water supply, and more than 2.6 billion lack access to improved sanitation. Water scarcity affects roughly 1-2 billion people worldwide and will continue to worsen, as 5% to possibly 25% of global freshwater use exceeds long-term accessible supplies. On an average, irrigation withdrawals exceed 15-35% of supply rates and are therefore unsustainable (Millennium Ecosystem Assessment 2005).

Most direct drivers of degradation in ecosystem services are growing in intensity in most ecosystems or at best are remaining constant (Millennium Ecosystem Assessment 2005). The result is that we live in an increasingly unsustainable world. This is the context in which we need to consider biodiversity. We are attempting to achieve conservation in a world that is living way beyond its means, and so the rapid loss of biodiversity, especially at the species level, should not surprise us.

The IUCN Red List

It is very important to assess the health of our global ecosystems by providing up-to-date information on the state and trends of wild species. The global tool for doing this is the IUCN Red List of Threatened Species (http://www.iucnredlist.org/).

The IUCN Red List Categories and Criteria (see http://www.iucnredlist.org/documents/redlist_cats_crit_en_v1223290226.pdf) are widely accepted as the most objective and authoritative system available for assessing the global risk of extinction for species (Lamoreux *et al.* 2003; De Grammont and Cuarón 2006; Rodrigues *et al.* 2006; Mace *et al.* 2008). Each species assessed is assigned to one of the following categories, Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern and Data Deficient, based on a series of quantitative criteria linked to population trend, population size and structure, and geographic range (Mace *et al.* 2008). Species classified as Vulnerable, Endangered and Critically Endangered are regarded as 'threatened'. The IUCN Red List Criteria can be used to assess the conservation status of any species, apart from microorganisms.

The IUCN Red List is compiled and produced by the IUCN Species Programme based on contributions from a network of thousands of scientific experts around the world in the IUCN Species Survival Commission. Assessments are impartial and peer-reviewed, providing objective data to support national, regional and global conservation priority setting. It is updated regularly and is freely available The Red List is used for many purposes, as summarised in Rodrigues *et al.* (2006) and Vié *et al.* (2009).

One of the IUCN Red List's main purposes is to highlight those species that are facing a high risk of global extinction. However, it is not just a register of names and associated threat categories but it is also a rich, expert-driven compendium of information on species' ecological requirements, geographic distributions (including maps) and threats. The Red List is used to determine what the challenges to nature are, where they are operating and how to combat them.

By assessing the threat status of species, the IUCN Red List has two goals: (i) to identify and document those species most in need of conservation attention if the global extinction rates are to be reduced, and (ii) to provide a global index of the state of change of biodiversity. The first of these goals identifies particular species at risk of extinction; the second goal focuses on using the data in the Red List for multi-species analyses in order to identify and monitor trends in species' status.

The diversity of species on earth is extraordinary. There are an estimated 8-14 million species in existence, 1.8 million of which have been identified and described. The estimates of how much of this diversity is being lost annually are disheartening, with the number of species assessed as threatened increasing every year. By 2008, 44,838 (2.5%) species had been assessed (Fig. 1), of which 869 (2%) have been classified as Extinct or Extinct in the Wild and 16,928 (38%) classified as threatened. Although only a small proportion of the world's species had been assessed by 2008, this sample indicates the serious conservation status of the species looked at so far, how little is still known and how urgent the need is to assess more species.

Despite the limited number of species assessed in relation to the total number of species known, and the significant number of Data Deficient species included in it, the Red List is still the largest dataset of current information

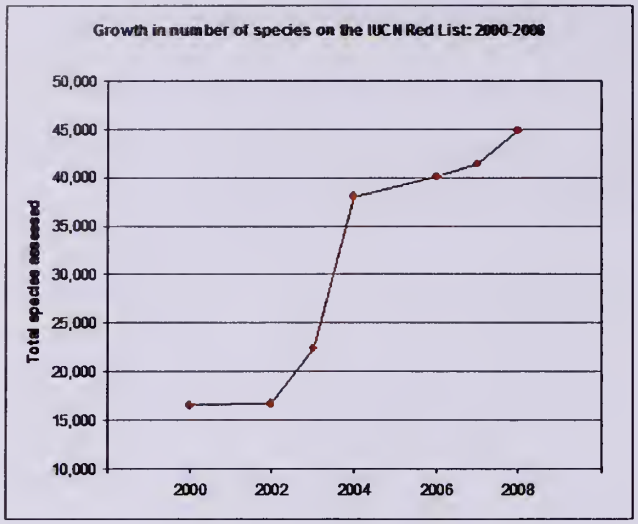

Fig. 1: Number of species appearing on each published IUCN Red List since 2000

on the conservation status of species. Completed and ongoing assessments include the following: BirdLife International bird assessments (updated 5 times since 1988); Global Mammal Assessment (completed in 2008, now being updated); Global Amphibian Assessment (completed in 2004, now being updated); Global Marine Species Assessment (ongoing); Global Freshwater Biodiversity Assessment (ongoing); and Global Reptile Assessment (ongoing). There are various plant and terrestrial invertebrate assessments that have also started and which are gathering speed.

STATUS OF TERRESTRIAL BIODIVERSITY

Comprehensive assessments, covering every species in a taxonomic group, have now been completed for amphibians, birds, mammals, cycads and conifers, warm water reef-forming corals, freshwater crabs and groupers. They are almost complete for sharks and rays, mangroves and sea grasses.

Status of Amphibians

Nearly one-third of the amphibian species (32.4%) are globally threatened or extinct, representing 2,030 species (Fig. 2). Thirty-eight species out of these 2,030 species are considered to be Extinct (EX), one is Extinct in the Wild (EW). Another 2,697 species are not considered to be threatened at present, being classified in the IUCN Categories of Near Threatened (NT) or Least Concern (LC), while sufficient information was not available to assess the status of an additional 1,533 species (Data Deficient (DD). It is predicted that a large proportion of these Data Deficient species are likely to be globally threatened.

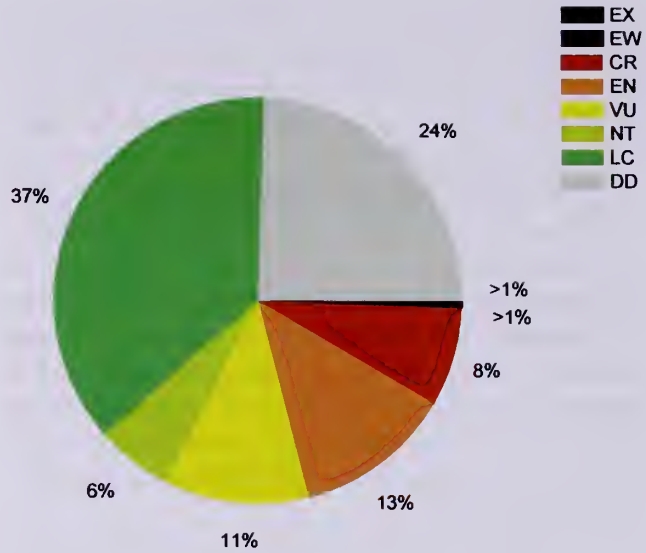

Fig. 2: The status of Amphibians by IUCN Red List categories EX = Extinct; EW = Extinct in the Wild; CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient

Status of birds

Birds are the best known taxonomic group on the IUCN Red List. Since 1988, there have been 5 comprehensive assessments of birds, with the most recent assessment, of all 9,990 known species, being completed in 2008. Less than 1% of bird species on the 2008 IUCN Red List have insufficient information available to be able to assess them beyond Data Deficient.

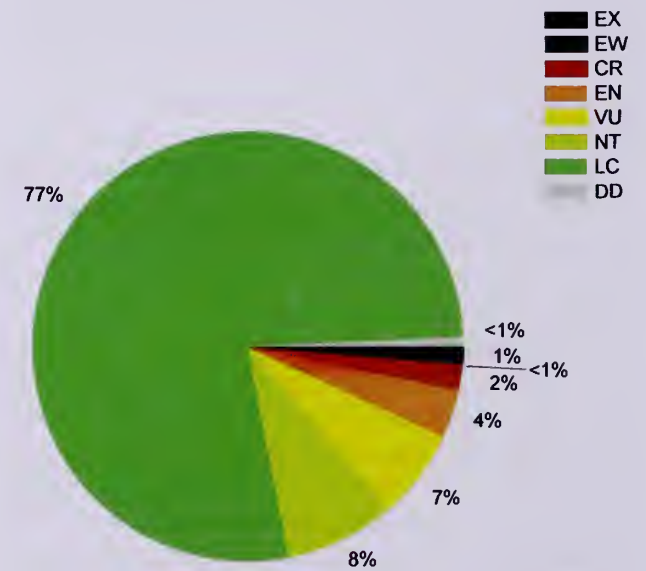

Fig. 3: The status of birds by IUCN Red List categories EX = Extinct; EW = Extinct in the Wild; CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient

It is clear, however, that being well-studied does not provide immunity from decline and high extinction risk. More than 1 in 8 bird species (13.6%) are globally threatened or extinct, representing 1,360 species (Fig. 3). Of these, 134 species (1%) are extinct, 4 species no longer occur in the wild, and a further 15 are Critically Endangered species flagged as 'possibly extinct', making a total of 153 bird extinctions since the year 1500.

Although 8,564 bird species (85.7%) are currently not considered threatened, 835 of these (8.4% of all known birds) are Near Threatened; the remaining 7,729 species are Least Concern.

Status of mammals

The mammal data on the 2008 IUCN Red List include 5,488 species, 412 subspecies and 21 subpopulations. The primary focus is, however, at the species level. This is the second time that all mammals have been assessed, the first being in 1996 (Baillie and Groombridge 1996).

Of the 5,487 mammal species assessed, nearly one-quarter of species (22.2%) are globally threatened or extinct, representing 1,219 species (Schipper *et al.* 2008) (Fig. 4). Seventy-six of the 1,219 species are considered to be Extinct (EX), and 2 Extinct in the Wild (EW). Another 3,432 species are not considered to be threatened at present, being classified in the IUCN Red List categories of NT or LC, while there was insufficient information available to assess the status of an additional 836 species (DD).

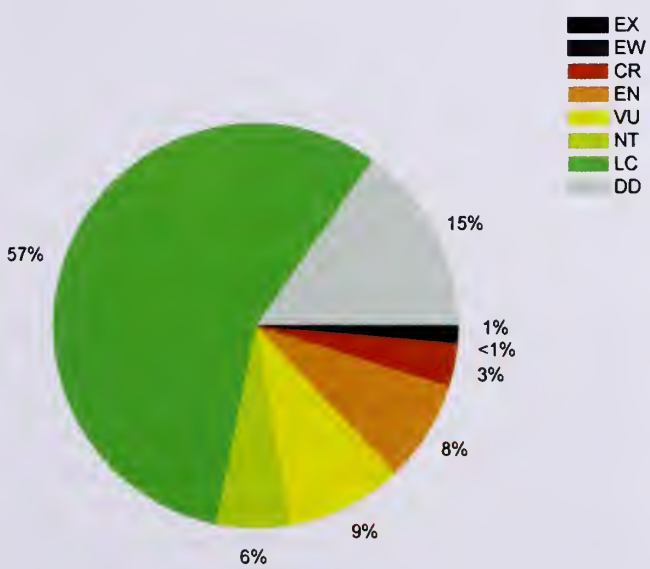

Fig. 4: The status of mammals by IUCN Red List categories EX = Extinct; EW = Extinct in the Wild; CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient

STATUS OF FRESHWATER BIODIVERSITY

IUCN is working with a number of partner organisations to fill the information gap on freshwater species. This is being accomplished by conducting assessments of all known species within the following priority groups: freshwater fishes, freshwater molluscs, dragonflies and damselflies, freshwater crabs and selected aquatic plant families. With the exception of the crabs, none of these assessments is yet complete globally.

There have, however, been some comprehensive regional assessments, in which every described species from a taxonomic group within a region has been assessed. This has enabled the identification of river or lake basins containing the highest levels of species richness, threatened species, restricted range species, migratory species and/or species important to the livelihoods of local communities.

The freshwater assessments completed for eastern and southern Africa have identified lakes Malawi and Victoria, the lower Malagarasi drainage (Tanzania), the Kilombero Valley (Tanzania) and the Southwestern Cape (South Africa) as containing some of the highest numbers of threatened species (Fig. 5).

Fig. 5: Distribution patterns of regionally threatened species for freshwater fishes, molluscs, odonates (dragonflies and damselflies) and crabs across eastern and southern Africa

Freshwater biodiversity is being threatened by a number of key impacts, including overexploitation, water pollution, river flow modification (including water abstraction), destruction or degradation of habitats, and invasion by invasive alien species (Millennium Ecosystem Assessment 2005; Dudgeon *et al.* 2006). Compounding these threats are the predicted global impacts of climate change leading to temperature changes and shifts in precipitation and runoff patterns (Dudgeon *et al.* 2006).

Using freshwater fishes as an example, being one of the most widely assessed of the freshwater species groups, the level, nature and distribution of major threats can be identified. Of the regions assessed so far, the Mediterranean and Malagasy endemic freshwater fish are shown to have the highest proportions of globally threatened species, with more than 50% of species threatened in each case, and southern Africa to have the lowest proportion, with 17% of species threatened (Fig. 6).

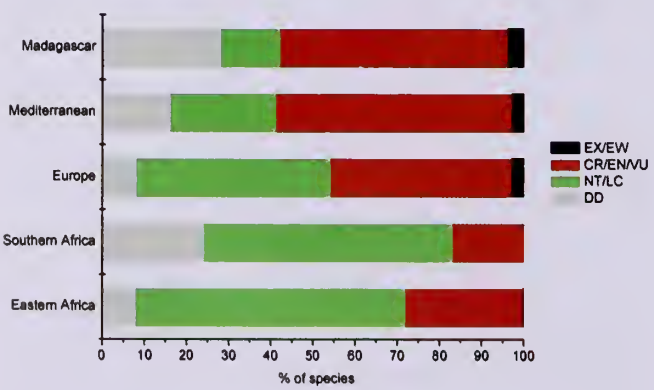

Fig. 6: Proportions of freshwater fish species by threat category in each of the regions assessed comprehensively. Only species endemic to each region are included

THE STATUS OF MARINE BIODIVERSITY

In recent years, there has been growing concern in the scientific community that a broad range of marine species could be under threat of extinction and that marine biodiversity is experiencing potentially irreversible loss due to overfishing, climate change, invasive species and coastal development (Roberts and Hawkins 1999; Dulvy *et al.* 2003).

In 2006, IUCN, Conservation International and Old Dominion University initiated an ambitious project (the Global Marine Species Assessment) to complete IUCN Red List assessments for a greatly expanded number of marine species. It is planned to complete Red List assessments for over 20,000 marine species by 2012. Much progress has already been made, and approximately 1,500 marine species have been added to the 2008 Red List. IUCN has now assessed all of the world's known species of sharks and relatives, groupers, reef-building

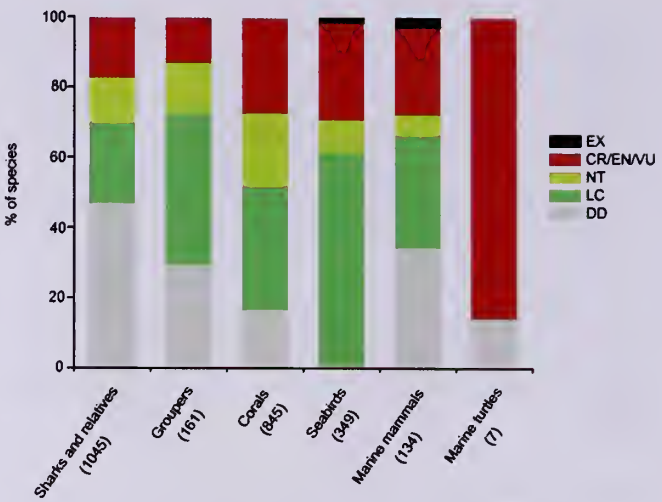

Fig. 7: Summary of 2008 Red List categories for completed clades of marine species
Number of species assessed in each group in parentheses
[black=EX; red=CR/EN/VU; yellow=NT; green=LC; grey=DD]

corals, (seabirds, marine mammals and marine turtles). Work on the sharks and rays is nearing completion. The overall results of these assessments (including the preliminary results for sharks and rays) are shown in Fig. 7.

The threat status of the different taxonomic groups varies quite widely. Overfishing and incidental mortality are particular common threats in the sea. However, with the reef-building corals, the situation is significantly different, as described below.

The world's known 845 species of reef-building zooxanthellate corals (Order Scleractinia plus the families Helioporidae, Tubiporidae and Milleporidae) were assessed for the first time (Carpenter *et al.* 2008). These reef-building corals provide the essential habitat for many species of fish and invertebrates, making them the most biologically diverse ecosystems in the ocean. More than one-quarter of these corals (27%) have been listed in threatened categories, representing an elevated risk of extinction. Over 20% of species are listed as Near Threatened and are expected to join a threatened category in the near future.

The primary threat to these reef-building corals is the increased frequency and duration of bleaching and disease events that have been linked to the increase in sea temperatures, a symptom of global climate change (Carpenter *et al.* 2008). These impacts are further compounded by anthropogenic threats, including coastal development, coral extraction, sedimentation and pollution. Another further threat to corals is ocean acidification as a result of increasing levels of atmospheric carbon dioxide. This is reducing ocean carbonate ion concentrations and the ability of corals to build skeletons.

Globally, the Indo-Malay-Philippine Archipelago or the 'Coral Triangle' has by far the highest number of coral species,

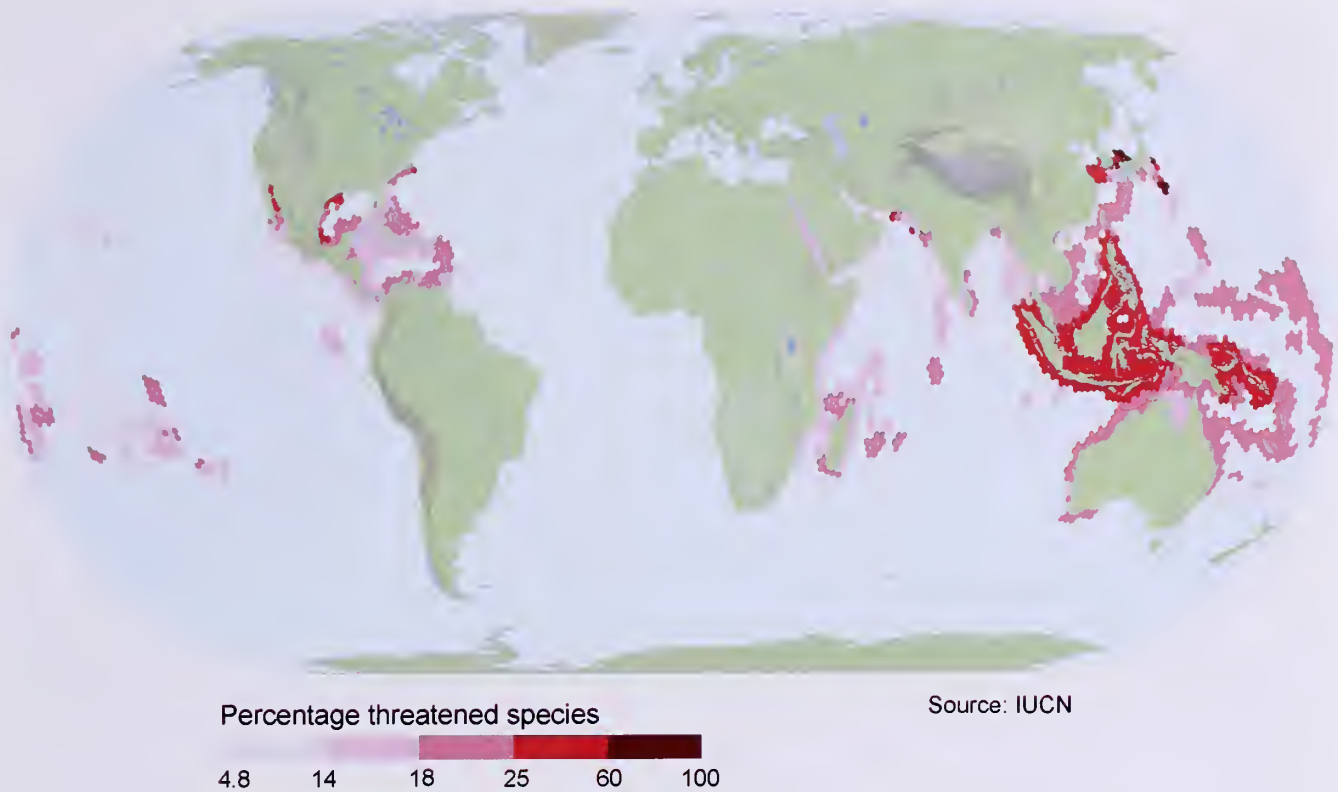

Fig. 8: Map showing the percentages of threatened reef-building coral species across the world

and also high percentages in threatened categories (Fig. 8). This region is also known as the epicentre of marine biodiversity and has the highest coral species richness. Coral reefs in the Caribbean region have been impacted by recent, rapid population decline of 2 key species: Staghorn Coral *Acropora cervicornis* and Elkhorn Coral *Acropora palmata*, both of which have been listed as Critically Endangered. In any region, the potential loss of these coral ecosystems will have huge cascading effects for reef-dependent species and for the large number of people and nations that depend on coral reef resources for economic and food security.

GLOBAL THREAT PATTERNS

Closer examination of some of these taxonomic groups reveals interesting patterns in the geographic concentrations of threatened across the globe. Fig. 9 shows the geographic patterns generated from overlaying the distributions of all threatened species in 4 taxonomic groups (birds, mammals, amphibians and corals). The contrast between the taxonomic groups demonstrates that geographic patterns of threat for one group do not predict the patterns of threat for another group; hence the importance of assessing the status of many groups of species.

There are important concentrations of threatened birds and mammals in South-east Asia, but the threat patterns of these two groups are markedly different in South America. Although nearly one-third of amphibians are at risk, threatened amphibians are found to be concentrated in a few areas only, especially in Mesoamerica, the northern Andes and the Greater Antilles. Conversely, most parts of the world have at least 1 threatened bird species, despite the fact that only 12% of birds are threatened.

LOOKING AT A FINER SCALE

The Red List criteria were developed for use at the global scale, at which the entire geographic range of a species is considered. However, IUCN is increasingly undertaking regional Red List projects. Regional and national lists are usually country-led initiatives and are not centralised in any way; they differ from each other widely in terms of scope and quality but can be very useful in guiding conservation work at subglobal levels.

In the Mediterranean region, for example, IUCN has assessed to date the following taxonomic groups: amphibians, reptiles, birds, mammals, sharks and rays, freshwater crabs and crayfish, endemic freshwater fishes, and dragonflies and damselflies (hereafter referred to collectively as dragonflies).

Overall, the proportion of threatened species in the Mediterranean (those classified as Critically Endangered, Endangered or Vulnerable), either at the global or regional

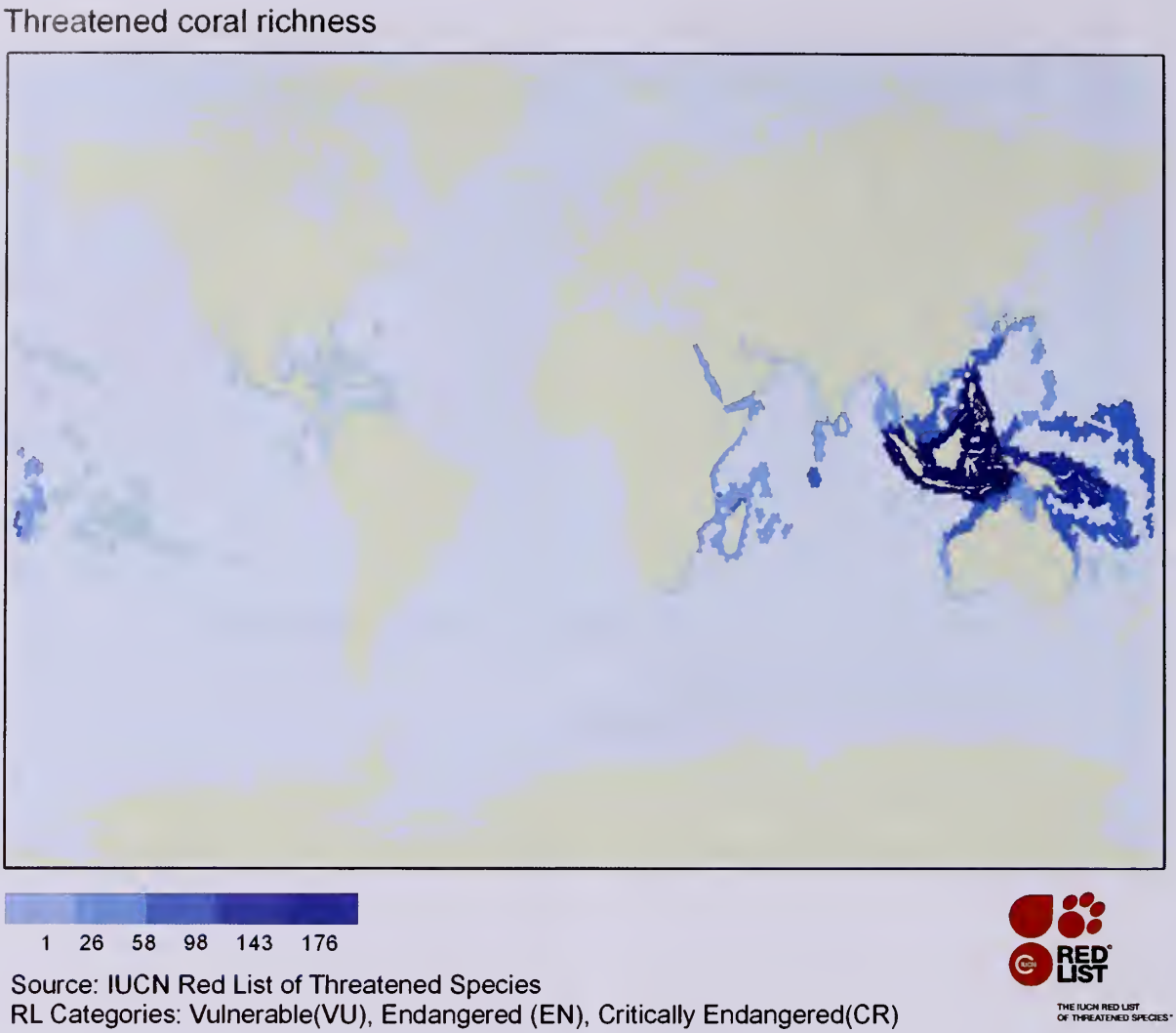
Threatened coral richness
1 26 58 98 143 176
Source: IUCN Red List of Threatened Species
RL Categories: Vulnerable(VU), Endangered (EN), Critically Endangered(CR)
RED LIST
THE IUCN RED LIST OF THREATENED SPECIES

Fig. 9: The geographic patterns generated from overlaying the distributions of all threatened species in four taxonomic groups (birds, mammals, amphibians and corals)

level, is about one-fifth (19%), and about 1% of the species are already extinct in the region. These percentages will be higher if some of the currently Data Deficient species prove to be threatened, as is likely to be the case.

Freshwater species have been mapped based on river basins flowing into the Mediterranean Sea and adjacent Atlantic Ocean river basins. Fig. 10 indicates concentrations of species at risk, in particular in the Iberian Peninsula, the Balkans, the western part of Greece and the area from Turkey down to Israel and the Palestinian territories.

BROADENING THE COVERAGE OF BIODIVERSITY ASSESSMENTS

A new initiative is being employed to broaden the taxonomic coverage of the IUCN Red List in order to enable a better understanding of biodiversity status as a whole and to identify key regions and taxa that require greater conservation attention.

This approach takes a random sample of 1,500 species from different taxonomic groups (Baillie *et al.* 2008). It allows the identification of the general level of threat to each group, the mapping of areas likely to contain the most threatened species and the identification of the main drivers of threats and helps pinpoint what key actions are required to address declines in the group as a whole.

The results of both the comprehensive and sampled assessments are starting to provide new insights into our understanding of the status of the world's species that can be built upon to track changes over time. The current plans to expand the number of species assessed for the Red List, using both comprehensive and sampled techniques, will, when implemented, increase the number of assessed species from 45,000 (on the Red List in 2008) to 1,30,000 (Fig. 11).

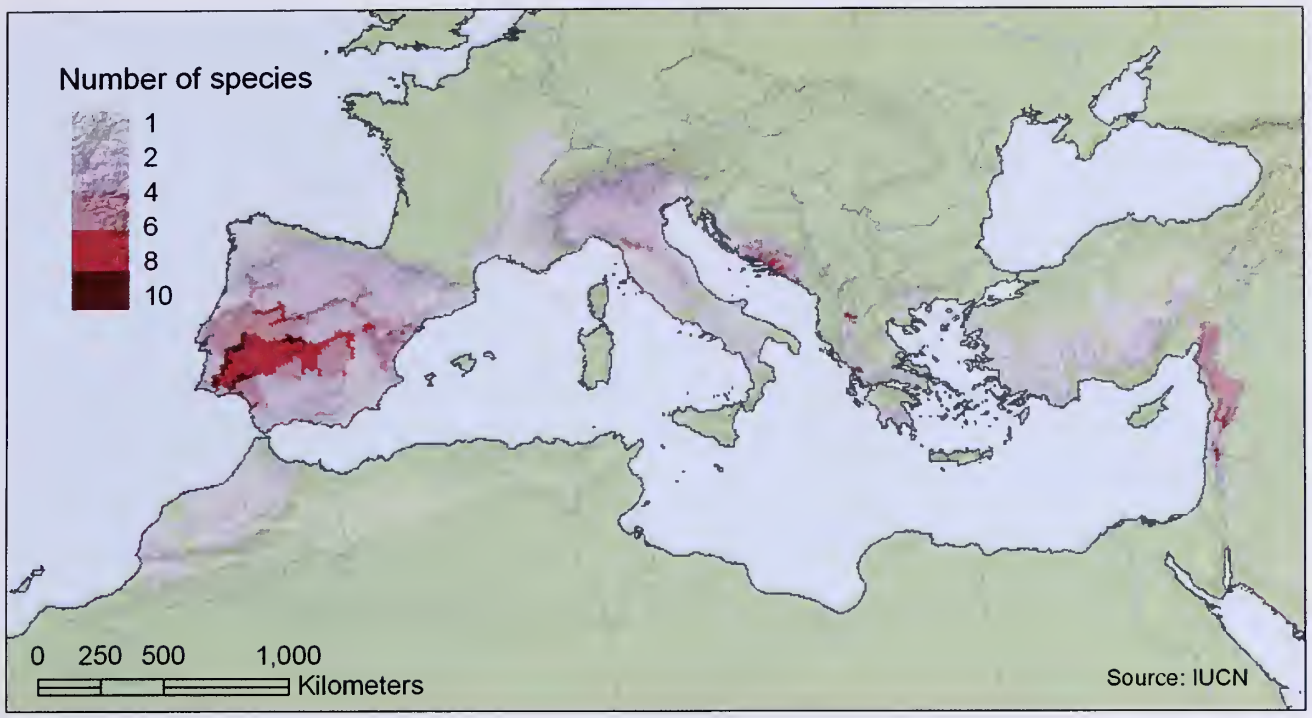

Fig. 10: Species richness of threatened freshwater amphibians, crabs, endemic fishes, mammals, dragonflies and reptiles in the Mediterranean basin

The first results of the sampled approach to Red Listing are now becoming available, specifically for reptiles and fishes, for neither of which the comprehensive assessments are complete yet. Across reptile groups, for example, the proportion of species threatened varies: 43% of crocodilians are threatened, compared with 12% of snakes and 20% of lizards. These patterns are likely to reflect differences in geography, range size, habitat specificity and biology, as well as threat intensity. Indo-Malaya is the most species-rich biogeographic realm for reptiles, and it also has the greatest density of threatened (CR, EN and VU) species (Fig. 12).

There are also some early results from this sampled approach for invertebrates. A map of the distribution of threatened freshwater crabs and dragonflies reveals some centres of threat for freshwater systems (Fig. 13). Marked concentrations of threatened species exist in Vietnam, Thailand, Cambodia, Malaysia and the Philippines in South-east Asia; Sri Lanka and the Indian Western Ghats in South Asia, and Colombia and Mexico in central and South America. These patterns are heavily influenced by the distribution of restricted range species.

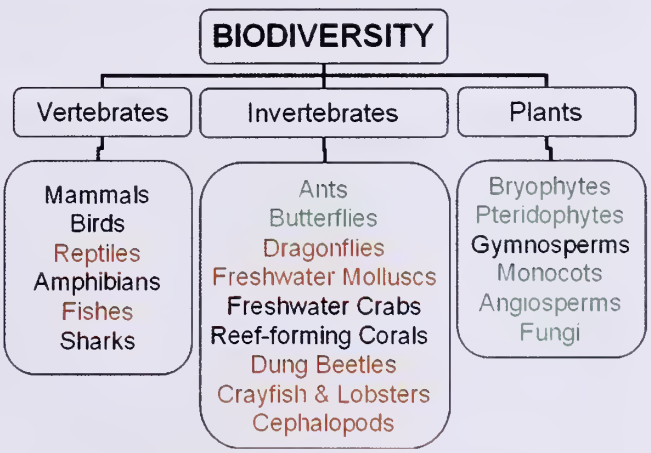

Fig. 11: Overview of IUCN Red List assessments: comprehensively assessed by 2008 (black); comprehensive assessments under way (red); statistically random samples planned or underway (green)

EXTINCTIONS

The global extinction of a species usually represents an end point in a long series of population extinctions. Creating an inventory of recent extinctions helps highlight the long list of unique species that have been lost forever. Understanding the extent of recent extinctions provides insights into historic extinction rates, which in turn can be compared to the rates over geological time to determine if current trends are normal or a cause for concern. An insight into the process of extinction can help us identify species that are at a risk of extinction and enable us to highlight taxonomic groups or species from specific regions that are or will be particularly prone to extinction.

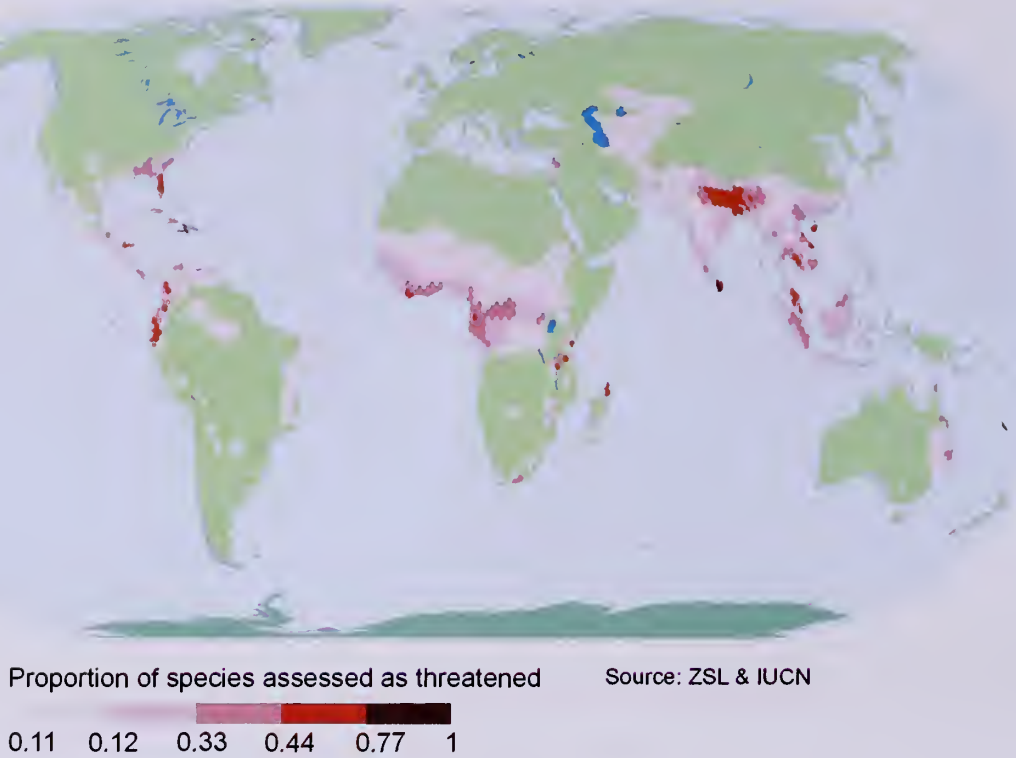

Fig. 12: Threatened species richness map for reptiles, based on a random sample of 1,500 species, 244 of which are threatened

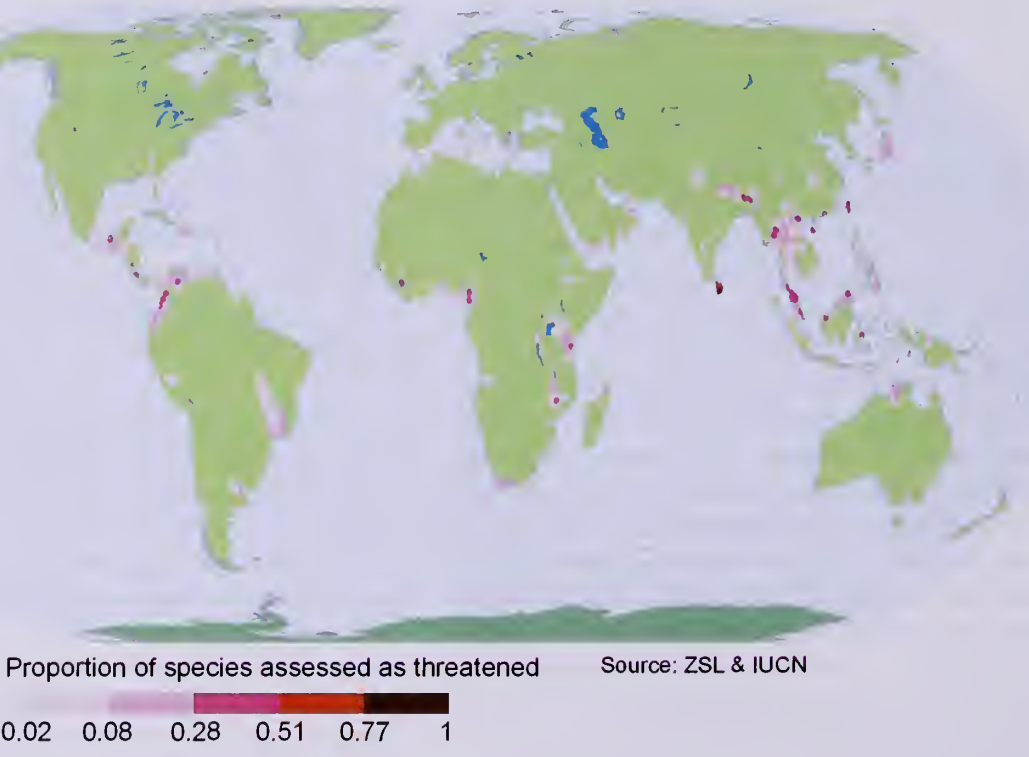

Fig. 13: Threatened species richness map for freshwater crabs (n = 210 species), and dragonflies and damselflies (n = 136 species)

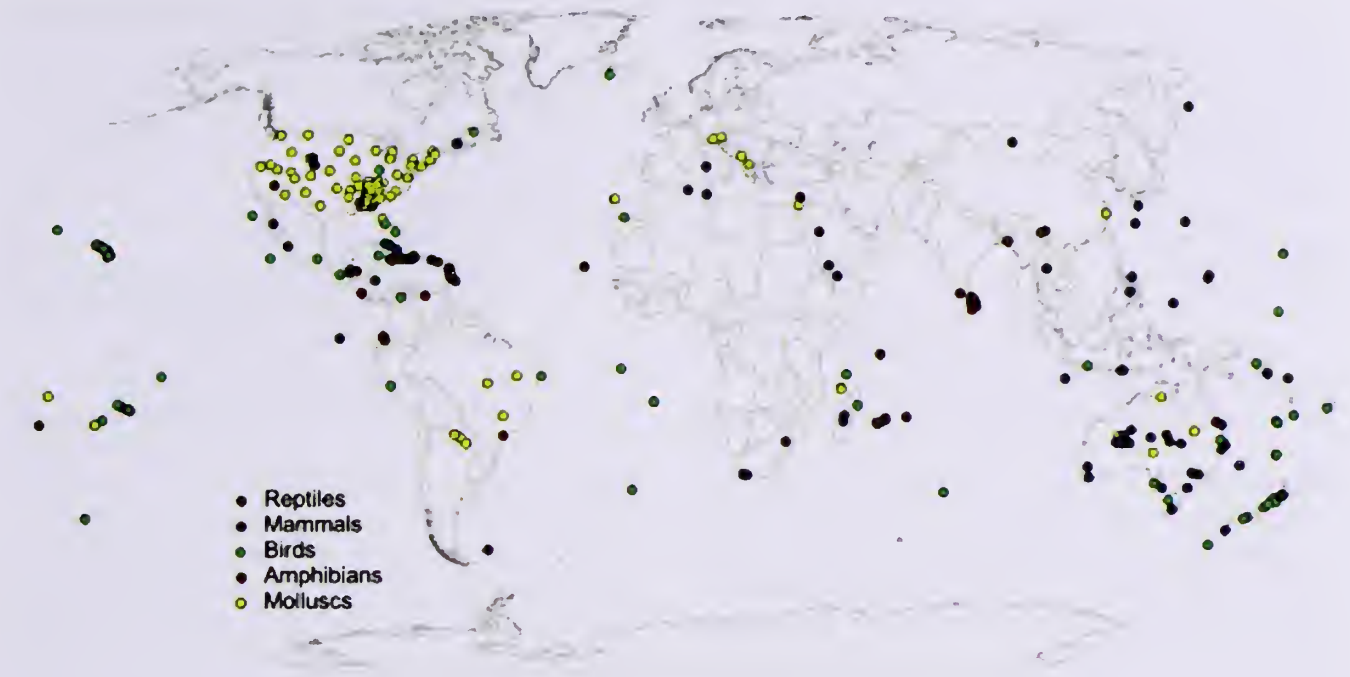

Fig. 14: The distribution of Extinct and Extinct in the Wild reptiles, mammals, birds, amphibians and molluscs

The world's list of documented extinctions continues to rise. The 2008 Red List includes 804 species listed as Extinct and 60 Extinct in the Wild. In the last 24 years there have been 29 documented extinctions, with recent extinction rates exceeding those from fossil records. With current extinction rates 100 to 1,000 times the natural (background) extinction rates, it is likely that the world is experiencing a net loss of species, perhaps for the first time in millions of years (Baillie *et al.* 2004).

There are major differences in the extinction patterns between the five taxonomic groups mapped in Fig. 14. Bird extinctions are overwhelmingly biased towards oceanic islands (including New Zealand), whereas the largest concentration of mammal extinctions is in Australia. Documented amphibian extinctions are focused on Sri Lanka, but this might be an artefact of under-recording extinctions elsewhere. Mollusc extinctions are concentrated in North American river systems, possibly another recording artefact. A detailed examination of bird extinctions since 1500 A.D. indicates that the pattern of extinctions might be changing. Although more than 80% of birds are found on continents, all extinctions prior to 1800 occurred on islands. This pattern has started to change in recent years, with more extinctions occurring on continents (Fig. 15).

THREATS

The major processes threatening species and driving extinctions are all of anthropogenic origin, and include habitat degradation and conversion (resulting in particular from agriculture, logging and residential and commercial development), overexploitation, invasive species, pollution and, increasingly, climate change (Figs 16, 17, 18).

Habitat loss and degradation are by far the greatest threat to amphibians at present (Fig. 16), affecting nearly 61% of all known amphibians (nearly 4,000 species), including 87% of the threatened amphibian species. The next most common threat to amphibians is pollution, which affects around one-fifth (19%) of amphibian species overall and 29% of threatened species. Although disease is a less common threat, it is much more likely to make a species globally threatened (Fig. 16). Indeed, the fungal disease

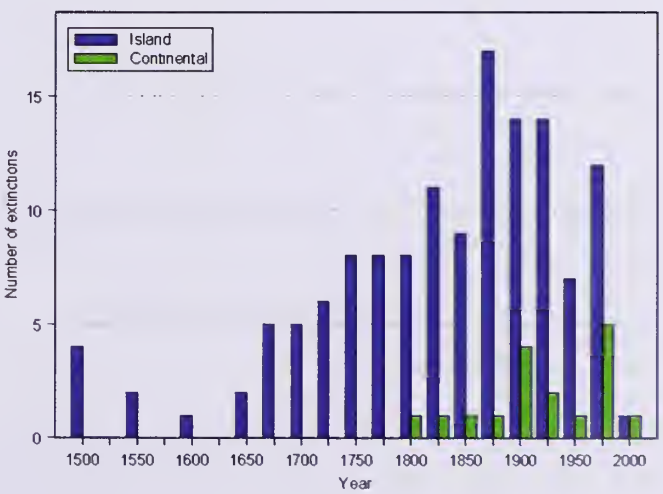

Fig. 15: The number of bird extinctions that have occurred on islands and continents since 1500 A.D.

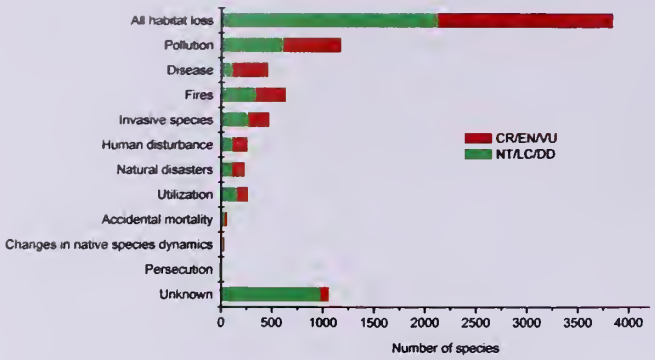

Fig. 16: Major threats to amphibians
(threatened species in red, non-threatened species in green)

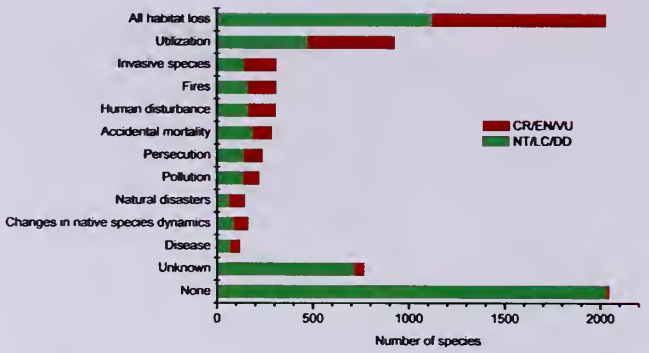

Fig. 17: Major threats to mammals
(threatened species in red, non-threatened species in green)

Chytridiomycosis is the major current driver of amphibian extinctions (Stuart *et al.* 2008).

By far the most significant threat to mammals is habitat loss, with over 2,000 species being negatively impacted (Fig. 17). The second most important threat is utilisation, with almost 1,000 species affected, mostly in Asia. The impact of invasive species is probably a little underestimated as only threats to extant species are included here and a significant proportion of species now considered extinct were affected by invasive species.

There is growing evidence that climate change will become one of the major drivers of species extinctions in the 21st century. IUCN is developing assessment tools to identify the potential effects of climate change on species. Susceptibility to climate change according to taxon-specific biological traits has been assessed, thereby allowing an

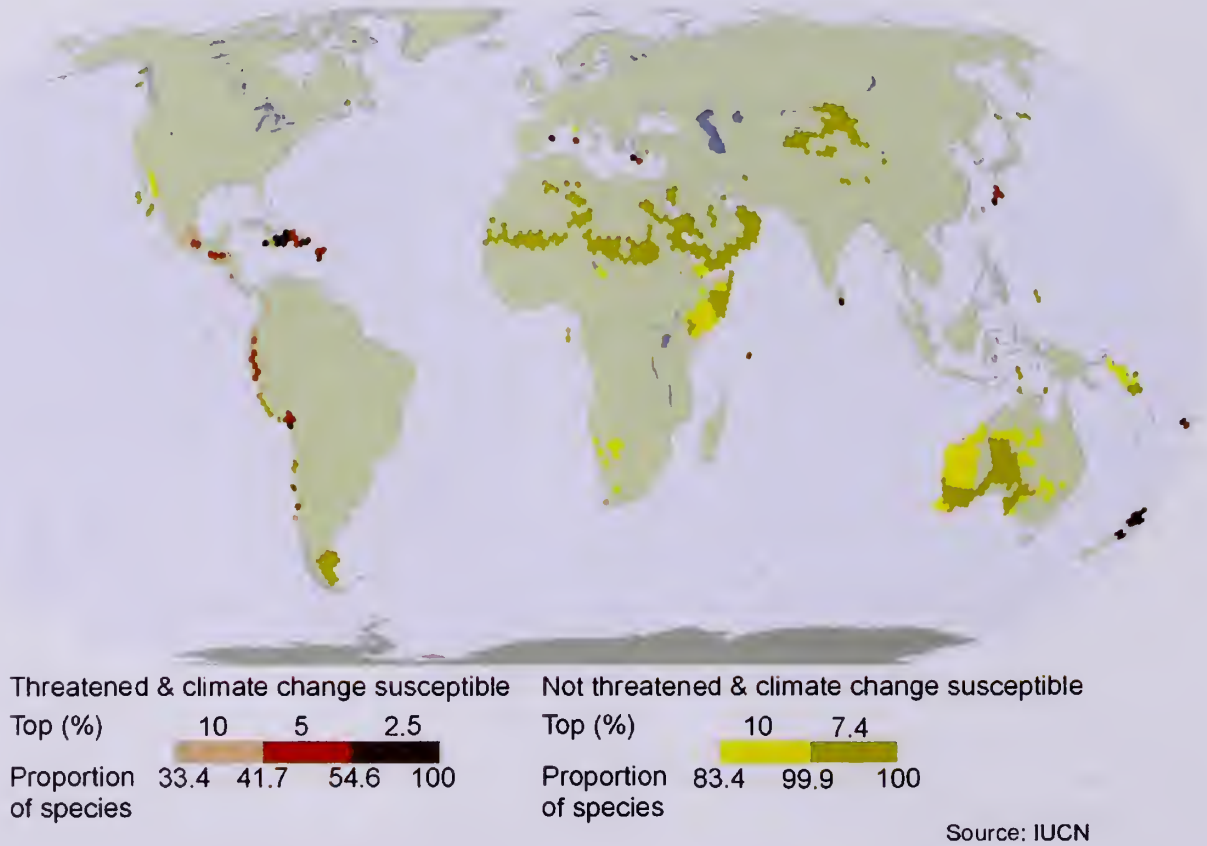
Threatened & climate change susceptible
Top (%) 10 5 2.5
Proportion of species 33.4 41.7 54.6 100
Not threatened & climate change susceptible
Top (%) 10 7.4
Proportion of species 83.4 99.9 100
Source: IUCN

Fig. 18: Areas containing high proportions of threatened and 'climate change-susceptible' (reds) and not threatened and 'climate change-susceptible' amphibian species (yellows) (expressed as the percentage of species in these categories relative to the total number of species occurring there). High concentration areas indicate those with the top 10%, 5% and 2.5% of values, and when these were not distinguishable, the nearest appropriate percentages were used

analysis of the potential impacts of climate change on species based on an analysis of these traits (Foden *et al.* 2009 for details). Using expert assessments for birds (9,856 species), amphibians (6,222 species) and warm-water reef-building corals (799 species), the taxonomic and geographical distributions of the species most susceptible to climate change were examined and compared to the existing assessments of threatened species in the 2008 IUCN Red List of Threatened Species™ (herein The IUCN Red List; IUCN 2008).

For amphibians, mapping the richness of threatened and 'climate change-susceptible' species (Fig. 18) highlights Mesoamerica, the northern Andes and the Caribbean. Additional areas of high concentrations include several Mediterranean islands and south-western Turkey; Seychelles; the southern Japanese islands; New Zealand's North Island; and Fiji. Areas of high concentrations of species assessed as not threatened but 'climate change-susceptible' include western and central Australia; the Solomon Islands; south-eastern South America; north-western Mexico; the arid region extending from the Western Sahara through the Red Sea Basin, south to the Horn of Africa and along the coastal regions of the Arabian peninsula; and the foothills surrounding the northern Himalayan Plateau. These geographic regions are defined by concentrations of species that are likely to become threatened due to climate change but which are not yet 'picked up' as threatened in the IUCN Red List.

ARE SPECIES BECOMING MORE OR LESS THREATENED WITH EXTINCTION?

In those taxonomic groups about which we know most, species are sliding ever faster towards extinction. IUCN Red List Indices (RLI — Butchart *et al.* 2004, 2005, 2007) show that trends in extinction risk are negative for birds, mammals, amphibians and reef-building corals (Fig. 19). Many more species are moving closer towards extinction, as measured by their categories of extinction risk on the IUCN Red List. The groups vary in their overall level of threat; for example, amphibians have a higher proportion of species threatened (i.e., lower RLI values) compared with mammals. Groups also vary in their rate of deterioration, with the rapid declines in reef-building corals since 1996 being driven primarily by the worldwide coral-bleaching events in 1998 and subsequently (Carpenter *et al.* 2008; Polidoro *et al.* 2009). The RLI for birds show that there has been a steady and continuing deterioration in the status of the world's birds between 1988 and 2008. Over these 20 years, 225 bird species have been up-listed to a higher category of threat because of genuine changes in status, compared to just 32 species down-listed.

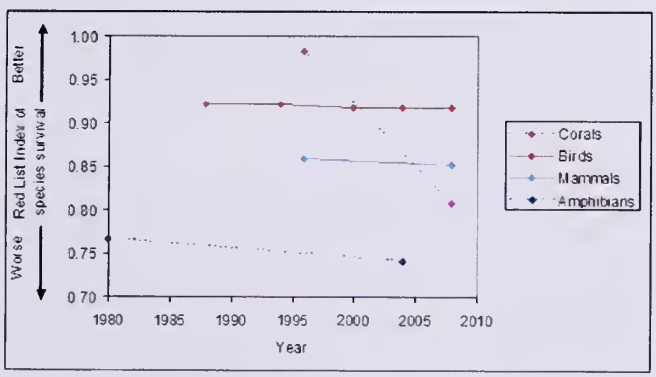

Fig. 19: Red List Index of species survival for corals, birds, mammals and amphibians, showing the proportion of species expected to remain extant in the near future without additional conservation action.
An RLI value of 1.0 equates to all species being categorized as Least Concern, and hence none being expected to go extinct in the near future. An RLI value of 0 indicates that all species have gone Extinct. (Number of non-Data Deficient species = 9,785 birds, 4,555 mammals, 4,416 amphibians and 704 corals (warm-water reef-building species only). Data are preliminary for amphibians in 1980 and corals in 1996.)

THREE CURRENT EXTINCTION CRISES

Looking at the Red List data as a whole, three major ongoing extinction crises are immediately evident, and these have already been highlighted in this paper. These are amphibians, corals and Asian large animals. There are probably other major crises also under way, but the Red List data are not yet complete enough to demonstrate this. Examples of likely crises include declines in marine species, especially due to bycatch, and declines of central and west African species due to bush meat harvesting.

Amphibians

As noted above, amphibians are the most threatened vertebrate group, with almost one-third of species listed as EX, EW, CR, EN or VU. At least 42% of all species are declining in population, indicating that the number of threatened species can be expected to rise in the future. In contrast, less than 1% of species show population increases. Although habitat loss clearly poses the greatest threat to amphibians, the fungal disease Chytridiomycosis is seriously affecting an increasing number of species and is the main driver of extinction over the last 3 decades (Stuart *et al.* 2008).

In response to the amphibian crisis, IUCN has developed the Amphibian Conservation Action Plan (Gascon *et al.* 2007). This provides a comprehensive framework for combating amphibian declines and extinctions. A major priority is to secure the habitats of the large number of threatened amphibian species that do not occur in any protected areas. There are at least 350, and possibly up to 600, such species, many more than is the case with birds or

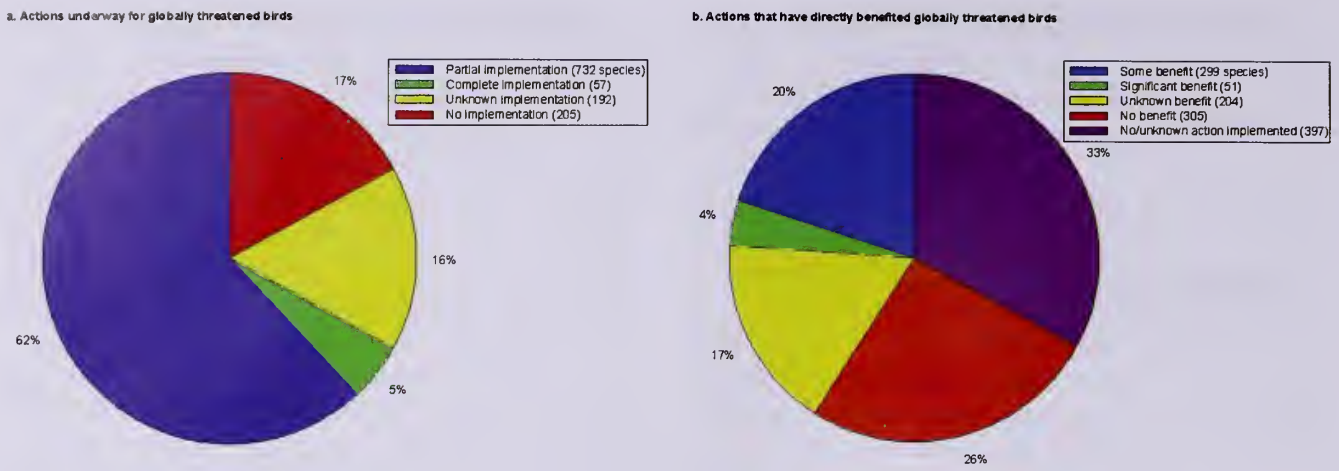

Fig. 20: Conservation action for birds: (a) percentage implementation and (b) percentage of those actions which have directly benefited threatened species

mammals (Rodrigues *et al.* 2004; Stuart *et al.* 2008). Furthermore, because of Chytridiomycosis, which cannot yet be treated in the wild and which can cause up to 100% mortality in certain species, many amphibian species can currently be saved only in captivity. This is obviously only an interim measure but one that, if successful, might buy some time for certain species while solutions to the Chytridiomycosis epidemic are sought. The Amphibian Ark Project (see http://www.amphibianark.org/) is a global programme to manage threatened amphibians in captivity until it is safe to reintroduce them into the wild.

Corals

The fastest rate of decline of the groups measured so far is seen in the reef-building corals. As mentioned above, the catastrophic declines in the abundance of corals are associated with bleaching and diseases driven by elevated sea surface temperatures. Coastal development and other human activities will have also impacted on the dramatic deterioration since the mid-1990s.

The impact of the decline and degradation of coral reefs on other reef-dwelling organisms is not yet known, but clearly the impacts on fishes and invertebrates could be alarming. Ex situ conservation might also prove to be necessary for corals and other coral-dependent species, especially as measures to reduce the level of CO_2 in the atmosphere are still a long way from having an effect.

Asian large animals

There have been massive decreases in wildlife populations in Asia in the last two decades, especially in South-east Asia and China. For example, there are now 10 Asian countries in the top 20 list for threatened mammals, and declines have also been most steep in the Indo-Malayan realm. The Indo-Malayan realm shows rapid declines in both birds and mammals, driven by the rapid increases in the rate of deforestation during the 1990s, particularly in the Sundaic lowlands of Indonesia and Malaysia, combined for mammals with high rates of hunting, particularly among medium- to large-bodied species. Indeed, there is a huge, and largely uncontained, threat of overexploitation affecting large-bodied taxa throughout Asia, including reptiles (including turtles) and fishes, as well as mammals and birds. Terrestrial, freshwater and marine species are all affected. There have been two likely mammalian extinctions in the last few years: the Baiji (or Yangtze River Dolphin) *Lipotes vexillifer* and the Kouprey *Bos sauveli*.

There is an urgent need throughout the region to address overexploitation through anti-poaching on the ground, as well as controlling trade in wildlife products. The loss of lowland forests for oil palm and other biofuels also needs to be addressed as a matter of urgency. In terms of addressing over harvesting, an initiative is needed not only to focus on anti-poaching (such as snare removal) but also to provide alternative livelihoods for local people, addressing the root causes of poaching, providing alternative protein sources and implementing capacity building and training programmes.

IS THERE ANY GOOD NEWS?

Looking at the raw Red List data can give misleading results, for example when comparing the headline statistics in 2007 and 2008. The number of threatened species has increased from 16,116 to 16,928 in association with the increase in species coverage from 41,415 species in 2007 to 44,838 in 2008. However, the overall proportion of threatened has dropped slightly, by 1%. Although this could represent

good news, an examination of the 223 species, which changed status for genuine reasons (i.e., became less threatened due to conservation efforts or became more threatened due to ongoing or increased threats), shows that only 40 of these were species that became less threatened, while 183 were listed in a higher category of threat.

Thirty-seven of the genuine improvements in status in 2008 were for mammals, with approximately 5% of threatened mammals demonstrating an increase in populations. It is estimated that 16 bird species have been prevented from going extinct between 1994 and 2004 due to conservation efforts; however, although (encouragingly) 67% of threatened species have some action under way, these actions have only benefited 24% of species so far (Fig. 20).

The 'take-home' message from these findings is that conservation can and does have a positive impact, but it is not yet being implemented at a level that can have a global impact on biodiversity trends.

DISCUSSION

Although a significant proportion of the world's species face extinction, it is not possible to quantify how many species are at risk because not all species have yet been named, the baseline checklists are constantly changing and the bulk of the world's species is yet to be assessed.

That said, the number of threatened species is increasing across virtually all the major taxonomic groups. Conservation measures are being taken for many species all over the world, ranging from species-specific actions to broad changes in national, regional or global policy. These responses in relation to individual threatened species are only just beginning to be measured, but many case studies show that well-focused species-centred actions can succeed in reducing the threat and improving the status.

The Red List species assessments are the most up-to-date, readily available and comprehensive inventory on species diversity. The information provided by the Red List shows what species are threatened, what the threats are and where they exist. Using this information to underpin conservation action will assist in preventing the decline of threatened species populations beyond the threshold of viability. With increasing knowledge of both where and how to act, focused conservation action works, although mitigating the extinction crisis will require much more rapid action. That means more resources, and resources better applied to safeguard habitats and improve the management of our natural resources.

ACKNOWLEDGEMENTS

I am very grateful to Rachel Roberts for comprehending the notes from my talk in Bengaluru to assemble this paper. This paper draws heavily on the work of others, especially the thousands of members of the IUCN Species Survival Commission. However, I particularly need to thank Craig Hilton-Taylor, Caroline Pollock, Jean-Christophe Vié, Mike Hoffmann, Janice Chanson, Vineet Katariya, Jim Ragle, Will Darwall, Kevin Smith, David Allen, Neil Cox, Jan Schipper, Kent Carpenter, Suzanne Livingstone, Beth Polidoro, Ariadne Angulo, Wendy Foden, Stuart Butchart, Thomasina Oldfield, Mary Seddon, Gordon McGregor Reid, Viola Clausnitzer, Vincent Kalkman, Yvonne Sadovy de Mitcheson, Sarah Valenti, Sarah Fowler, Ben Collen, Mala Ram, Nadia Dewhurst, Neil Cumberlidge, Jonathan Baillie, Georgina Mace, Annabelle Cuttelod, Nieves García, Dania Abdul Malak and Helen Temple.

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CONSERVATION STATUS OF THE LAST SURVIVING WILD POPULATION OF HANGUL OR KASHMIR DEER *CERVUS ELAPHUS HANGLU* IN KASHMIR, INDIA

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The Kashmir Deer or Hangul *Cervus elaphus hanglu*, a critically endangered deer, is one of the four easternmost subspecies of Red Deer found in Asia and is endemic to the mountains of Kashmir in the north-western Himalayan region of India. At present, the only viable Hangul population is confined to the 141 sq. km Dachigam National Park (NP), with a few isolated Hangul herds in its adjoining protected areas. Here, we present our recent (2001-2008) assessment of the Hangul's status and conservation in the Kashmir region based on intensive monitoring in Dachigam NP and extensive surveys carried out all over the Hangul's erstwhile stronghold and range. Our range-wise surveys indicate that at present the last surviving and genetically viable Hangul population of 140-170 individuals is restricted to Dachigam NP. A few isolated Hangul populations are also present in the adjoining conservation reserve areas of Bren-Nishat (11 Hangul), including Cheshmashahi Forest Reserve, south-west of Dachigam NP, where a direct sighting of two Hangul females was made in autumn; Khrew (2-6 Hangul); Khanagund (1-2 Hangul); Shikargah (7-12 Hangul) and Overa Wildlife Sanctuary (6 Hangul). Besides, Hangul use the Surfrao and Akhal blocks of Sindh Forest Division, north-east of Dachigam NP, during spring and summer. A group of about 12 Hangul was sighted north of the holy Amarnath cave, which falls just outside the demarcated boundaries of the Overa-Aru and Baltal-Thajwas wildlife sanctuaries, east of Dachigam NP. The current population trends indicate that the species could go extinct if the necessary serious interventions are not made immediately. This study attributes the decline in Hangul population to low breeding, female biased sex ratio, the problem of survival of the young, inadequate recruitment of fawns to adulthood due to factors such as considerable predation by the Leopard *Panthera pardus* and Asiatic Black Bear *Ursus thibetanus*, poaching and continued degradation of Hangul summer habitats in Upper Dachigam, along with biotic interference in winter habitats, and the movements of Hangul in summer to unprotected areas in Sindh Forest Division outside Dachigam NP and the excessive biotic interferences therein. Significant parasitic infestations have also been found in faecal samples of Hangul in Dachigam NP. The Hangul population in Dachigam NP and its adjoining areas thus needs immediate attention. An intensive population monitoring programme, studies of the reproductive ecology and movement patterns of the Hangul and monitoring its health to understand better the factors affecting the population growth and biology and other aspects of Hangul ecology are required for effective management and long term conservation. Population studies indicate a decrease in genetic heterozygosity over time and thus there is a need for urgent measures to arrest the loss in heterozygosis and declining trend of the Hangul population. There is an urgent need for a Hangul recovery plan to be developed that includes field surveys to identify corridors to help dispersion and reintroduction of Hangul to its former distribution range and habitat protection in Upper Dachigam and other potential Hangul habitats outside Dachigam. A captive breeding plan for the Hangul is important to repopulate existing good habitats in the Hangul range, beginning with the Shikargah-Overa ranges in Lidder Valley.

Key words: Hangul, *Cervus elaphus hanglu*, Red Deer, Dachigam, viable population, Zanskar Range, Kashmir

INTRODUCTION

The Hangul or Kashmir Stag *Cervus elaphus hanglu*, listed as a critically endangered deer in the IUCN's Red Data Book (Simon 1966; IUCN 2006), is one of the four easternmost subspecies of Red Deer that are found in Asia (Grzimek 1990; Geist 1998). However, unlike Red Deer and Wapiti *Cervus canadensis*, which have a wider distribution, extending from western Europe to central Asia, and North America and Canada (Ellerman and Morrison-Scott 1951; Flerov 1952; Corbet 1978), the Hangul has had a restricted global distribution. Being endemic to Kashmir, it was once distributed widely in the mountains of Kashmir (Gee 1965; Schaller 1969) along the Zanskar mountain range in the North-West Himalayan Biogeographic Zone (2A) (Rodgers and Panwar 1988) of India. The shikar map of Kashmir prepared by the then Maharaja of Jammu and Kashmir, Hari Singh, depicts the past distribution of the Hangul in an arc of 64 km width, north and east of the Jhelum and the lower Chenab river. The distributional range extended from Shalurah and Karen in the Kishenganga catchment over to Dorus in Lolab Valley and the Erin catchments in Bandipora in the north to

Paper read at the International Conference on 'Conserving Nature in a Globalizing India' at Bengaluru; February 17-19, 2009

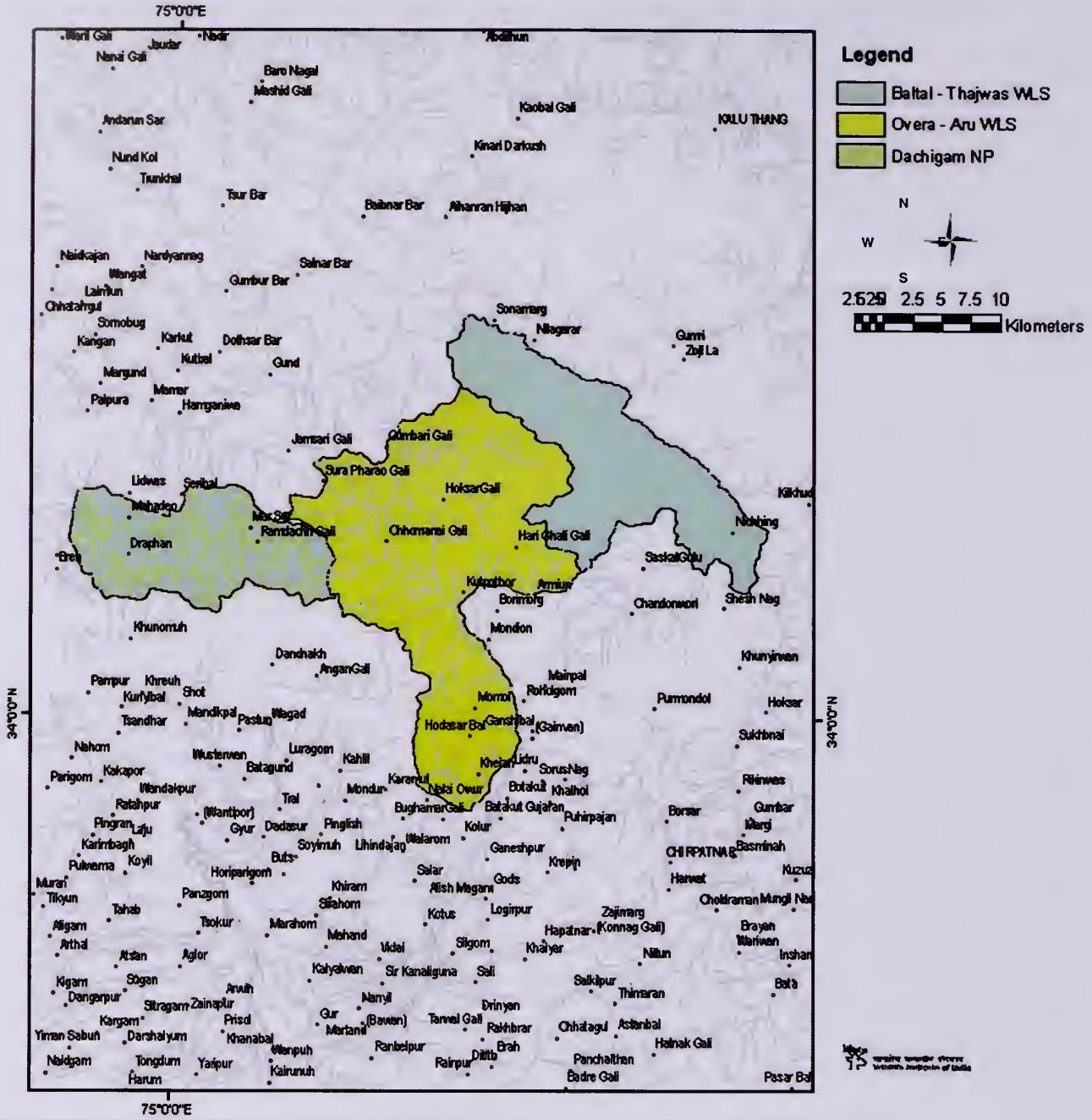

Fig. 1: Dachigam National Park and adjoining Protected Areas

Marwah/Wadwan in Kishtwar High Altitude National Park (NP) in the lower Chenab Valley, and Ramnagar in the south (Lydekker 1924; Holloway and Schaller 1970; Holloway and Wani 1970) (Figs 1, 3) through the present day Baltal-Thajwas Wildlife Sanctuary (WS), Tral Conservation Reserves (Shikargah, Panner & Khiram), Overa-Aru WS, Desu WS and Rajpariyan (Daksum) WS. The Gamgul Siya-Behi Sanctuary in Himachal Pradesh, on the state border, was the only area outside Jammu and Kashmir that probably retained a few Hangul (Holloway 1971).

During the recent past, the Hangul appears to have been wiped out from its past distribution range, possibly due to large scale biotic interference owing to habitat fragmentation and degradation, and poaching. At present a viable population of Hangul occurs only in Dachigam NP, with a few isolated populations in the adjoining areas.

The estimated population of Hangul in Kashmir in 1900 was 3,000-5,000 and in 1947, there were *c.* 2,000 Hangul still surviving. But 10 years later, the population drastically reduced to about 400 individuals (Gee 1966). The estimates

of the Hangul population between 1969 and 1970 range from not more than 180 individuals (Schaller 1969) to 140-170 (Holloway 1971).

Estimates over the years of the Hangul population in Dachigam and adjoining areas show wide fluctuations, with a drastic decline during the recent past from the 1980s (Fig. 2). The decline in the Hangul population from 2,000 in 1947 (Gee 1965) to 140-170 in 1970 (Holloway 1971) and 175 in 1992 has been attributed to the continued degradation of the Hangul's summer habitat of Upper Dachigam (Holloway 1971; Kurt 1978) and the continued irregular biotic interference in its winter habitat of Lower Dachigam in the past, besides excessive poaching.

Despite the critically endangered status of the Hangul, the species had been very poorly studied compared to its conspecifics the Red Deer of Europe and Wapiti, and other deer species in India. Some information, however, existed on the Hangul, mostly in the form of brief accounts by hunters (Ward 1921; Stockley 1936) stressing shooting exploits and naturalists stressing conservation problems (Talbot 1959; Gee 1965; Schaller 1969; Holloway and Schaller 1970; Holloway and Wani 1970; Caughley 1970; Kurt 1978; Oza 1977; Shah *et al.* 1984; Mishra 1986; Iqbal 1986; Inayatullah 1987). Some accounts deal with general information about the Hangul (Lydekker 1915; Flerov 1952; Whitehead 1972; Lowe and Gardiner 1974; Schaller 1977; Groves and Grubb 1987; Geist 1998) with the exception of the few brief survey reports and natural history accounts mentioned above, carried out prior to the 1990s, and the routine annual Hangul population census carried out by the Wildlife Protection Department of the Jammu & Kashmir Government, no intensive studies had been carried out on the aspects of Hangul ecology prerequisite for its effective long term survival and conservation planning. Here, we present the results of our surveys (2001-2008) and intensive study on Hangul ecology in Dachigam NP and the Hangul's erstwhile distributional range in Kashmir. We also summarize the critical factors that affect the Hangul and its habitat and are prerequisite for the effective management and long term conservation and survival of the Hangul and its habitat.

STUDY AREA

The area of the intensive study, Dachigam NP, holding the last genetically viable population of the Hangul, lies between 34° 05' 00" N to 34° 10' 32" N and 74° 53' 50" E to 75° 09' 16" E. The mountain ranges enclosing Dachigam NP are a part of the great Zanskar Range, which forms the north-west branch of the Central Himalayan Axis, bifurcating near Kullu (Himachal Pradesh) and terminating in the high twin peaks of Nun Kun (7,135 m). The entire Hangul distributional range is characterised by complex crystalline rocks, granites, gneisses and schists which form the core of the Zanskar Range, a fold of which encloses the Dachigam NP. This complex is partly sedimentary and consists of slates, phyllites and schists with embedded crystalline limestone (Lydekker 1876). Most of the sediments composing these ranges have been laid from the Cambrian to the Tertiary period, and ridged and folded up over the ages (Wadia 1961). The area exhibits a variety of vegetational types characterised by the habitat, form and density of dominant species and controlled by a number of factors including habitat conditions, exposure, altitude and, above all, the degree of biotic interference (Singh and Kachroo 1978). The low lying areas, from 1,700 to 3,000 m, have a complex mixture of vegetation types, with broad leaf mesophyll forests of *Acer caesium*, *Morus alba*, *Ulmus* spp., *Rhus succidiadiana*, and *Juglans regia*, *Parrotiopsis jacquemontiana* and a variety of conifers such as Deodar *Cedrus deodara*, Blue Pine *Pinus wallichiana*, Spruce *Picea smithiana* and Fir *Abies pindrow* growing in an altitudinal sequence (Holloway 1971; Singh and Kachroo 1978). The upper reaches, from 3,000 to *c.* 4,700 m, comprise a vegetation gradient of a subalpine forest community followed by scrub vegetation of Birch *Betula utilis* and Rhododendron *Rhododendron* spp. interspersed with herb-rich grasslands and meadows above 3,300 m. This zone gradually merges into the zone of permanent snow, which is above 3,500 m (Holloway 1971; Singh and Kachroo 1978). The main vegetation types in the area as per Champion and Seth (1968) are typical of Himalayan moist temperate forests: they are of the subalpine forest and alpine forest types.

The climate of the study area may be described as sub-Mediterranean to typically temperate, with higher degrees of variation in precipitation and dryness. Generally, two spells of dryness are experienced, one in June and another in September-November. Snow is the main source of precipitation and in some parts melts till June. Four distinct seasons occur in a year: spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). The monthly mean temperatures recorded during the study period ranged between a maximum of 32 °C in August 2002 (late summer) and a minimum of -5.8 °C during January 2003 (mid-winter) (Ahmad 2006). The soil depth on the slope in the study area from the lower to the middle reaches is less than 25 cm, and hence falls under the category of very shallow soils (Bhat 1985). The annual minimum and maximum rainfall of Dachigam and adjoining areas have been calculated as ranging between 32 mm and 546 mm (Bhat 1985).

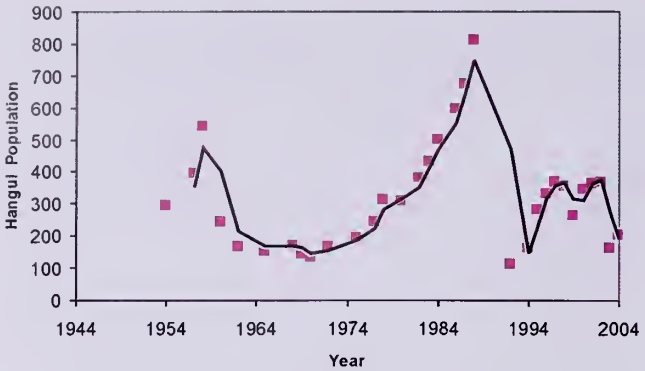

Fig. 2: Population trend in Dachigam and adjoining areas from 1954 to 2004 (Gee 1966; Holloway 1971; Kurt 1969; Department of Wildlife Protection 1970 till 2004; Qureshi and Shah 2004; Ahmad 2006: this study)

METHODOLOGY

This ecological study on the Hangul was aimed at enhancing the scientific knowledge on the aspects of Hangul ecology that are prerequisite for its effective management and long term conservation. We carried out intensive studies on Hangul ecology in Dachigam NP on a regular basis (2001-2004) besides extensive surveys (2004-2008) in the Hangul's erstwhile range areas, including Dachigam NP. Hangul distribution, abundance, habitat use, food and feeding habits were investigated along stratifies trails/transects (1 to 2 km length), and survey blocks, on a rotational basis 3-4 times a month in different day hours. For intensive studies in Dachigam NP, the study area was stratified into 7 transects varying in length between 1 and 2 km and in 7 survey blocks (Fig. 4), based on differences in altitude, slope, aspect, floristic composition, degree of human disturbance and administrative beat. Each transect was monitored on a rotational basis three times a month according to the line transect method (Burnham *et al.* 1980), and blocks were intensively surveyed along trails, *nullahs* (streams) and contours according to the trail monitoring method (Rutledge 1982) on a rotational basis four times a month in different seasons and different time periods of the day, for data collection and investigations on Hangul distribution, abundance, habitat use, food and feeding habits. Data based on direct Hangul sightings were collected on these transects and survey blocks. For each sighting, several parameters were recorded, including the time of animal sighting, group size and group composition (males, females, young/yearlings and unknown sex). Besides, data on indirect evidence of Hangul (dung/pellets) wherever found were also collected in 59 (2 × 20 m) belt transects randomly laid in 5 survey blocks for habitat use and dietary investigations. Attempts were also made to investigate the feeding habits of Hangul based on scan sampling following Altman (1952) or following the groups.

Besides the intensive surveys in Dachigam NP, an extensive reconnaissance of the erstwhile stronghold areas of the Hangul's pre-1947 distributional range was carried out to assess the present status and distribution of the Hangul outside Dachigam NP. The survey areas were selected based on unconfirmed reports from the Hangul's past distributional range areas, extending from Keran in the Kishanganga catchment area and Dorus in Lolab Valley of Bandipora to Kishtwar NP. The areas covered in the surveys and interviews with local people and livestock herders include (1) Surfrao and Akhal forest blocks of Sindh Forest Division, and Baltal-Thajwas WS, north and north-east of Dachigam NP; (2) Brein, Nishat and Cheshmashahi Conservation Reserve to the west and south-west of Dachigam NP; (3) Hajan and Satura blocks of Tral Conservation Reserve and Shikargah/Panner Conservation Reserves south-east of Dachigam NP; and (4) Overa-Aru WS in the far eastern part of Dachigam NP (Fig. 1).

In each of these areas, the survey units were selected based on unconfirmed reports of Hangul presence available with the forest and wildlife staff and local people. A forest and wildlife beat was considered as a unit for sampling Hangul presence and habitat assessment (Jhala *et al.* 2005). Furthermore, to ascertain the status of the Hangul in its western range areas, we interviewed local people, livestock herders and army personnel deployed in Gurez and Bandipora about the past and current occurrence of the Hangul.

Hangul habitat suitability and biotic interference assessment was also carried out in Dachigam NP and its adjoining areas to identify the potential units in the Hangul's past distribution range areas outside Dachigam NP for relocation/reintroduction of some Hangul and the possibility of monitoring them continuously.

Hangul relative abundance was estimated following Burnham *et al.* (1980). The chi-square test and ANOVA were performed for analysis of population data. All statistical analyses were performed using the computer program SPSS following Norris (1990). The typical group size was computed following Jarman (1974). Hangul densities were estimated from the Hanguls seen on the transects. Visibility correction was not employed. These densities are merely relevant in terms of relative comparisons. The Hangul population viability analysis (PVA) and the possible risk of extinction of the Hangul in the near future was evaluated using the widely used structured PVA (Caughley 1994; Akcakaya 2000a,b) with the help of the software program Vortex 9.6 (Lacy 2000). This model was run on the basis of population characteristics reported for the Red Deer and Hangul, including data gathered for the Hangul during this study.

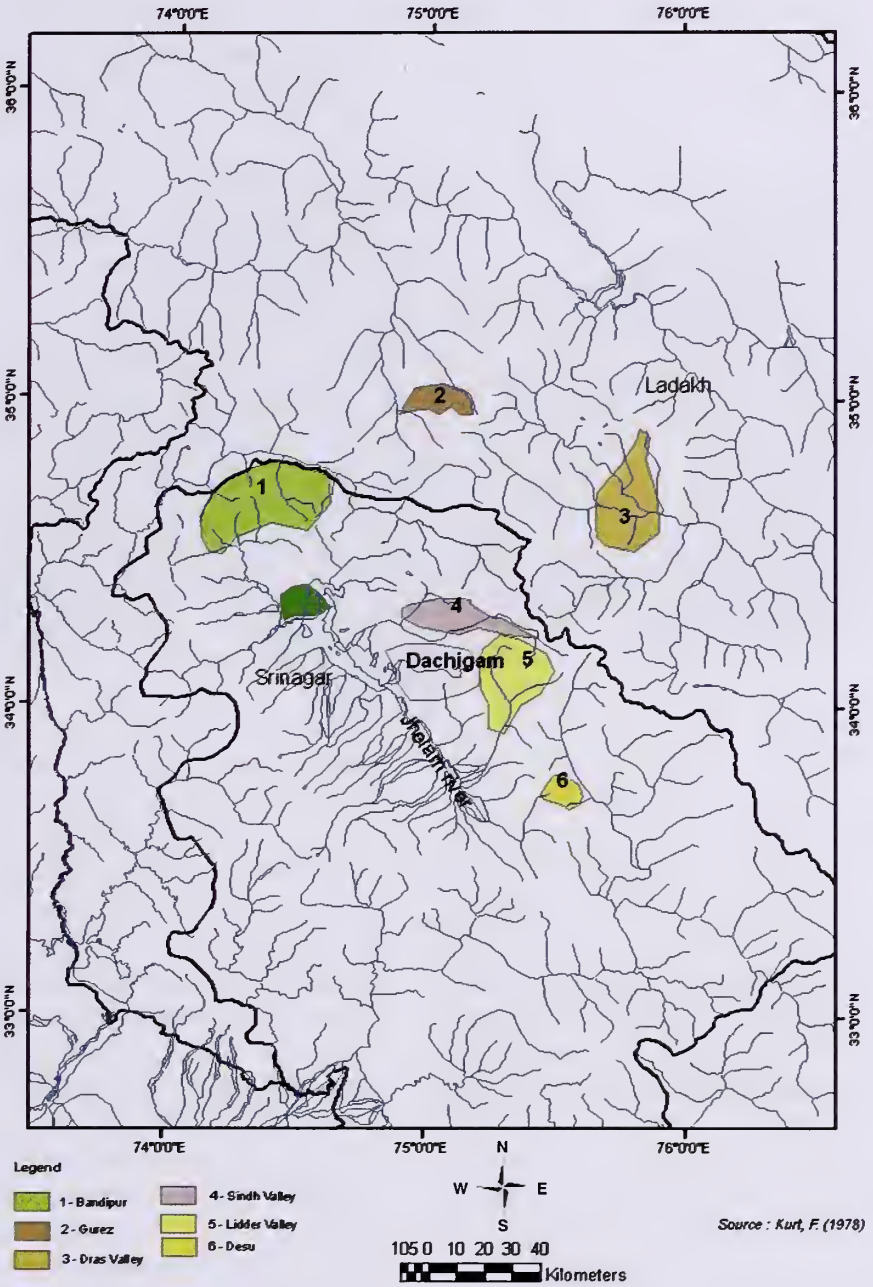

Fig. 3: Past distribution of Hangul in Kashmir Valley

During our intensive studies in Dachigam NP, 693 surveys in the form of trail or transect monitoring were carried out in 7 transects and 5 fixed survey blocks that involved a time and distance effort of 1,839 hours and 5,668 km, respectively, distributed almost equally in the 4 seasons (416 hours and 1,263 km in spring; 473 hours and 1,428 km in summer; 418 hours and 1,276 km in autumn; and 532 hours and 1,701 km in winter).

RESULTS

Our intensive studies and extensive range-wise surveys in almost all the erstwhile areas of the Hangul in Kashmir clearly indicate that at present the last genetically viable population of the Hangul occurs only in the 141 sq. km Dachigam NP in Kashmir and that a few isolated populations occur in the adjoining conservation reserves of Bren-Nishat (11 Hangul), including Cheshmashahi Forest Reserve, south-west of Dachigam NP, Khrew (4-6 Hangul); Khanagund (1-2 Hangul); and Shikargah (7-12 Hangul) and in Overa WS (*c.* 6 Hangul). Besides, some stray Hangul groups have been sighted in Sindh Forest Division to the north and north-west of Dachigam NP, including 6 Hangul (1 male, 3 female and 2 young) sighted on the trail between Surfrao and Akhal

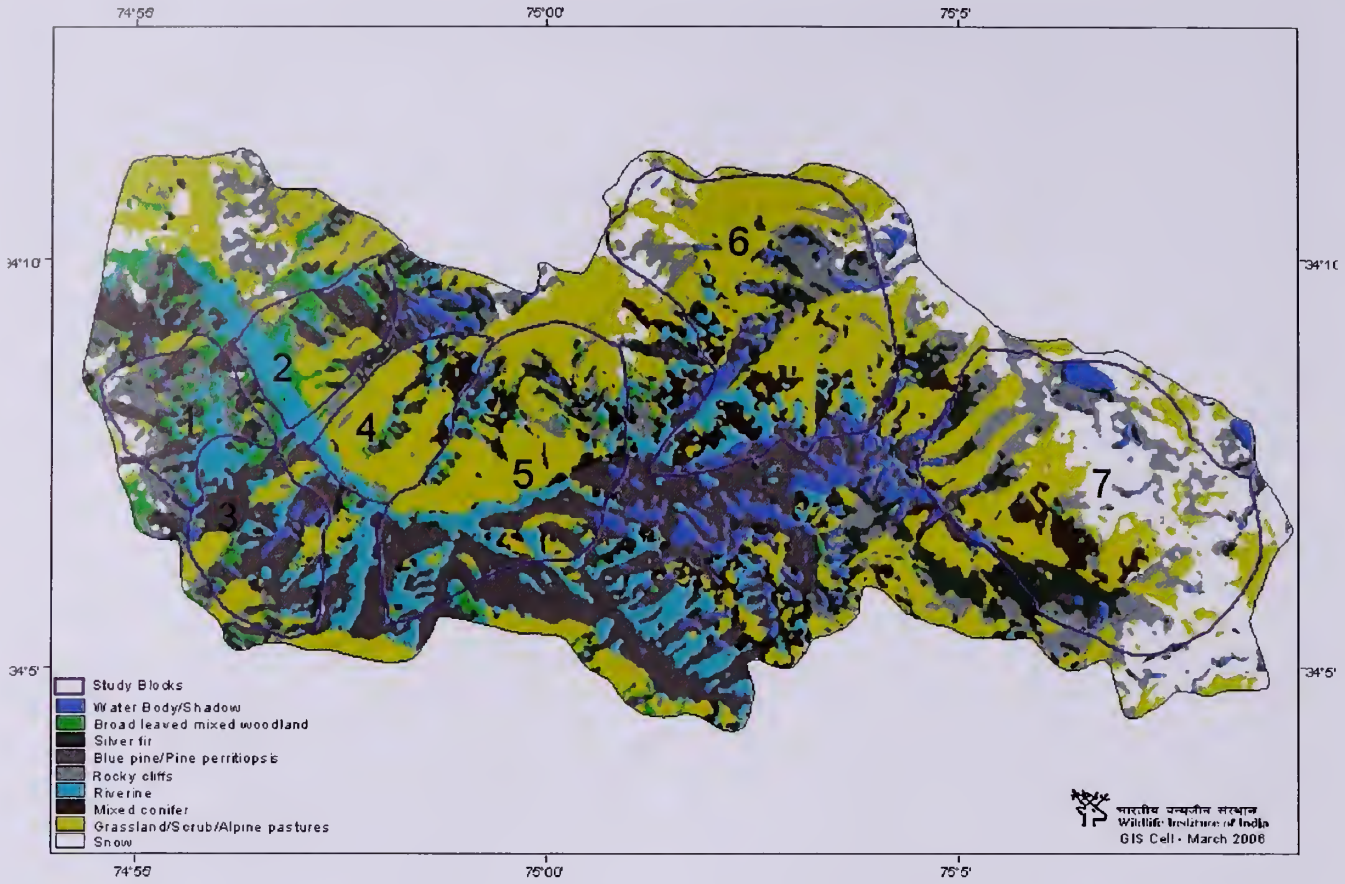

Fig. 4: Location of study blocks in DNP

blocks of the Sindh Forest Division. Of 5 Hangul individuals which fell into the Sindh river near Kangan Forest Block in June 2006, 2 females were rescued and brought to Pahalgam Zoo, in south Kashmir; these were subsequently preyed upon by Leopard *Panthera pardus*.

In 2004, we estimated the Hangul population to be between 146 and 249, with a mean of 197 animals. In 2006, the Hangul population was estimated between 117 and 190 animals, with a mean of 153 animals, whereas in 2008 the population estimates turned out to be between 170 and 190 animals. There appears to be a marginal decline in the Hangul population between 2004 and 2006, which is statistically significant (t=2.24, P=0.06). The Hangul population showed a decreasing trend in recent years in Dachigam and adjoining areas.

In Dachigam NP, during February 2001 to December 2004, a total of 326 Hangul sightings were recorded, and the maximum Hangul sightings (101) were recorded in winter, followed by 85 Hangul sightings each in spring and autumn. During summer only 55 Hangul sightings were recorded. Hangul encounter rates both per hour effort and per kilometre walk showed a decrease from spring to summer, followed by a gradual increase from summer through autumn to winter. The maximum Hangul encounter rates (2.02 individuals/hour effort and 0.67 individuals/km walk) were recorded in spring, followed by 1.17 individuals/hour effort and 0.55 individuals/km walk recorded in winter. The minimum encounter rates of 0.41 individuals/hour effort and 0.14 individuals/km walk were recorded in summer. Hangul encounter rates/hour effort or per kilometre walk showed significant differences between different seasons (F=42.218, P=0.001 and F=42.44, P=0.001, respectively). The overall Hangul encounter rates/hour effort and per kilometre walk also showed significant differences between the study blocks (F=173.71, P=0.001 and F=193.37, P=0.001, respectively). The overall (weight for block area) Hangul density in the intensive study area of Dachigam NP was 5.60±1.13 SE Hangul/sq. km, and it varied between the seasons. The maximum Hangul density (9.02±0.14 SE/sq. km) was recorded in winter, and the minimum Hangul density (0.71±0.05 SE/sq. km) was recorded in summer.

The survey results also indicated wide fluctuations in overall Hangul group size and composition between the seasons. The group size varied from 55 individuals in spring and 40 individuals in winter to 1 individual in the summer. The overall Hangul mean group size varied between seasons, with the largest in spring (95% confidence limit 5.36 ±1.28

(*c.* l)) followed by (4.86 ±0.99 *c.* l) in winter. The smallest Hangul mean group size of 1.10 ±0.33 *c.* l. was recorded in summer. The overall typical Hangul group size was 14.11 individuals, and it varied between the seasons from 17.50 individuals in spring to 5.28 individuals in summer. The overall Hangul group composition was 4.30 male, 7.52 female and 5.20 young, and it varied between seasons. As with the Red Deer, the Hangul showed wide sexual segregation. Out of 326 Hangul sightings recorded, Hangul males occurred singly (17% sightings), or in groups of their own, whereas in 18.46% of the sightings, the Hangul groups comprised females only. In 29.54% of the sightings, the Hangul was found in groups of females and fawns. The overall Hangul sex ratio was 23.23 males per 100 females (SE=2.60) and 29.95 young per 100 females (SE=1.90). The overall fawn-to-female ratio was 29.95±1.90 (SE) young/100 females. The Hangul population in Dachigam NP shows a 7.9% increase in growth rate (r=0.079 SD; (r)=0.129); the population will increase to 291.74 Hangul SE=1.51) and stabilise by the 20th year, given that the carrying capacity of the habitat is 300 and there is a low level of poaching (5%). The sensitivity analysis indicated that there is a 25% chance of extinction in 100 years. The population analysis indicates a decrease in genetic heterozygosity over time.

Outside Dachigam NP, the Surfrao/Akhal blocks of Sindh Forest Division, north and north-east of Dachigam NP, Shikargah and Khiram conservation reserves and Overa-Aru WS, to the east and south-east of Dachigam NP, were observed to support a considerable relic population of the Hangul.

DISCUSSION

The current trend of the Hangul population indicates that the species could go extinct if serious management and conservation interventions are not made immediately. Our studies and survey observations indicate that some of the major issues concerning the decline in the population and long term conservation and survival of the Hangul are the highly skewed female biased sex ratio and very low fawn-to-female ratio, predation by Leopard, poaching to some extent and summer dispersal of the Hangul to unknown unprotected areas in the north-west of Sindh Forest Division, outside Dachigam NP, besides some biotic interference by livestock grazers (Iqbal *et al.* 2004; Qureshi and Shah 2004; Ahmad 2006; Ahmad and Khan 2007).

The study results indicate that the social structure, distribution and movement patterns of the Hangul in Dachigam NP are closely associated with the season, topography and changing vegetation and biotic interference patterns over the seasons. In the later half of winter and early spring, i.e., between February and May, there is fresh growth of grasses, herbs, sedges and dwarf shrubs, and flowering of trees, resulting in the downward movement of Hangul from higher to lower elevations and congregation in the ravines, as the mountain peaks surrounding the Park remain under snow cover. In contrast, in summer, the Hangul remains dispersed at higher altitudes moving even outside the Park. This is evidenced by the far fewer Hangul sightings and encounter rates during summer. The deciduous forest conditions, together with the fresh forage, probably improved the visibility of and favoured the sighting of comparatively large group sizes in springs and winter compared to summer and autumn, when the shrub and tree canopy cover impaired animal sightings in Dachigam.

The occurrence of the Hangul in Overa-Aru WS presents an excellent opportunity for a comparative study of its population with that of Dachigam NP. Such a study can throw light on the possible interaction between the two populations. Furthermore, Overa-Aru WS, together with Shikargah/Khiram Conservation Reserve, with which it shares a boundary (Fig. 1), similar to Dachigam NP in topography, climate, and vegetation, can prove to be a suitable habitat for a second viable population of the Hangul outside Dachigam NP. In the past as well, the largest population of Hangul outside Dachigam NP was believed to be supported by the Overa-Lidder forests (Inayatullah 1987). However, the latest census, conducted in March 2000 by the Department of Wildlife Protection, indicates that the Hangul population within and around Overa-Aru WS is 37, which include 12 males, 20 females and 5 fawns. This gives the Sanctuary added importance and calls for special efforts towards the conservation and management of its habitats and wildlife therein. Except for the annual census, conducted by the department, there has hardly been any efforts so far to ascertain scientifically the actual size of the Hangul population of Overa-Aru. As such, information regarding the herd composition sex ratio and home range of the Overa Hangul is lacking. Overa-Aru WS and Sindh Forest Division, falling in the distributional range of the Hangul, are closely linked with Dachigam NP through forest corridors which show a strong vegetational contrast with Dachigam NP as they have been subjected to various types of biotic interferences. With the exception of some steep slopes, the natural vegetation has been replaced in these forest corridors in the valley by cultivated plants along roadsides, and stream sides, and in orchards (Kurt 1979a,b).

In Gurez, some isolated Hangul have also been found to occur. This population might possibly be the only resident western population of Hangul in its erstwhile distribution range. However, this needs to be verified. This area could as

well serve as an ideal habitat for the reintroduction of more Hangul.

The livestock grazing and biotic interferences seemed to show some significantly positive impacts on the movement patterns of Hangul in Dachigam NP. Block 5 of Dachigam NP, in which average livestock dung densities of 25.40 ±17.67/sq. km of cattle and 132.77 ±92.83/sq. km of sheep/goat were recorded during the grazing season (summer-autumn) was used less frequently by Hangul during this period compared with the very frequent sightings in the same block in the non-grazing season (winter-spring). The Hangul encounter rates during summer were lowest in Block 5 (N=2). The Hangul encounter rates, however, increased in this block in late autumn (N=35) and winter (N=180). This block, having its upper reaches above 3,000 m, connected to the subalpine and alpine meadows of Upper Dachigam, experiences heavy livestock grazing and biotic disturbances in summer and a downward migration of grazers during autumn. This possibly forces the Hangul to restrict its movements to away from these two blocks.

Similar patterns have been reported in the displacement and dispersion of Elk and Red Deer away from the areas used by livestock in summer (Dalke *et al.* 1965; Mackie 1970; Lonner 1977; Franklin and Lieb 1979; Skovlin and Vavra 1979; Clutton-Brock *et al.* 1982; Clutton-Brock and Albon 1989). As the densities of livestock increased, the effects on Elk and Red Deer increased. The Sambar has also been found to avoid areas which are used by livestock and pastoral settlements (Sathyakumar 1994; Khan 1995). Long term scientific studies and monitoring of the impacts of grazing and habitat degradation on Hangul should continue in the area through the establishment of 3 to 5 exclosures of dimensions 50 × 50 m in both Lower and Upper Dachigam.

Both direct and indirect evidence suggest that the Surfrao, Akhal and Kangan blocks of Sindh Forest Division attract large populations of Hangul particularly in summer and the beginning of autumn. This might possibly be because the subalpine and alpine meadows of Dagwan, Nagaberan and Marsar of the upper reaches of Dachigam NP, where Hangul used to range in the past (Schaller 1969; Holloway 1971; Kurt 1978) during this season, have been under heavy pressure from biotic interference in the form of excessive livestock grazing by local people, the Gujjar and Bakerwal, and sheep and goats of the Government Sheep Breeding Farm, resulting in the disappearance and displacement of the Hangul from these areas, with the exception of few strays. Significant efforts (30 surveys; 150 hours spent and 300 km walked each in summer and autumn) were expended to assess these subalpine and alpine meadows of Upper Dachigam only during summer and autumn as they were inaccessible during winter and spring due to heavy snow cover. But no direct sightings or indirect evidence of Hangul were obtained in these meadows of Dagwan, Nagaberan and Marsar of Upper Dachigam (Dagwan, Nagaberan and Marsar of the upper reaches of Dachigam NP). Secondly, since most of the drainages (*Nullahs*) in Dachigam NP were observed to be dried up throughout the year, probably due to the impact of global warming, since the glacial areas of Upper Dachigam have been observed to be snowless even during the beginning of summer. The non-availability of water in the near vicinity might have forced the Hangul, especially lactating females in summer, to move towards the disturbed habitats in and outside Dachigam. This might as well be acting as one of the factors for fawn mortality to predators or even sheep dogs. This, however, needs to be scientifically assessed: in one incident, out of a group of 5 or 6 Hangul that were observed crossing a river in Kangan Block of Sindh Forest Division, only 3 animals could be rescued, whereas others fell in the river and died. Initiation of a GPS-satellite telemetry study can help track the movement patterns of Hangul outside Dachigam NP, and in demarcating the actual area on either side of Dachigam used by Hangul that could be declared as a sanctuary to serve as a summer home for them.

The very low Hangul sex ratio is of great concern for the long term survival of the Hangul population. The sex ratio of the Hangul population based on our 2006 extensive survey observations in Dachigam NP and adjoining areas was 21 (SE=2.07) males per 100 females. In 2004, it was observed to be 19 (SE=1.33) males per 100 females, with no significant difference between 2004 and 2006 (t=-0.96, p=0.37). The fawn-to-female ratio seems to be worrying as it shows a significant decline (t=3.4, p=0.01), to 9 (SE = 2.11) fawns per 100 females in 2006 from 23 (SE=2.93) fawns per 100 females in 2004. Our intensive monitoring and observations in Dachigam NP alone, based on all the 326 Hangul sightings made with binoculars, so as to avoid any visibility bias, revealed a female biased overall sex ratio of 23.23 males per 100 females (SE=2.60) and 29.95 young per 100 females (SE=1.90). This observed Hangul sex ratio is lower than the reported ideal sex ratio of 50 to 66.66 males/100 females for Red Deer (Darling 1937; Whitehead 1972; Bonenfant *et al.* 2004). The Hangul sex ratio has never been at such low levels in the past. The Hangul sex ratio in the past is reported to have ranged from 25 to 30 males per 100 females (Holloway 1971; Stockley 1936; Inayatullah 1987).

The very low sex ratio and fawn-to-female ratio could be attributed to significant predation by Leopard on all sex and age classes of Hangul and of Black Bear principally on young deer. Our studies on predator-prey relationships at

Dachigam NP have revealed that the Leopard *Panthera pardus* and the Asiatic Black Bear *Ursus thibetanus* are the major predators in the area and that the Hangul formed a major proportion (about 25%) of the Leopard diet at Dachigam NP (Iqbal *et al.* 2004; Ahmad 2006). In other words, 60% of the biomass of the Leopard diet is constituted by Hangul. This is, however, a grey area of information, and it needs more research. There is a possibility of Hangul predation by other predators such as the Himalayan Yellow-throated Marten *Martes flavigula* in the area which need to be explored. The information obtained by research on the species, particularly on the breeding biology and movement patterns, is still inadequate, and a regulated monitoring of the Hangul populations on a long term scientific basis, particularly during the fawning season and at the time of rut, will help determine the causes of low reproduction and fawn survival in Dachigam and other range areas of the Hangul.

The supplementary food that is being provided to the Hangul in the form of salt and willow leaves at certain fixed spots alone has resulted in habituating Hangul movements around these particular spots. The provisioning of supplementary food in winter is reported to be useful for both male and female deer, preventing greater winter male mortalities in the Red Deer and Elk (Clutton-Brock and Albon 1989; Smith 2001). The same is recommended to be distributed evenly along the main *nullahs* so as to ensure the availability of food and minerals to the Hangul in its distributional areas in Dachigam with minimal efforts during severe weather conditions in winter and spring. The tall grassland and scrub habitats of Dachigam have been used by Hangul as shelters, sources of foraging substrates and as places in which to escape from predators. Their loss due to frequently observed wildfires may represent a significant change in the suitability of these habitats for Hangul use. The establishment of fire lines using the plantation of fire-proof *hatab* (*Parrotiopsis jacquemontiana*) trees to provide natural fire lines in the forests and grasslands of Dachigam may be tried to control fires in the grassland and scrub habitats of Dachigam NP. Controlled and scientific fire management is a tool that will help conserve these pristine Hangul habitats.

An increase in the Hangul population of Dachigam, modelled on the basis of population characteristics reported and studied (2001-2008) for the Hangul and other closely allied subspecies, particularly Red Deer, with a growth rate of 7.9% (r=0.079 SD, (r)=0.129) is indicated. The population will increase to 292 Hangul (SE=1.51) and stabilise by the 20th year, given that carrying capacity of habitat is 300 and there is a low level of poaching (5%). The growth rate without carrying capacity i.e. the growth rate of Hangul without specifying any carrying capacity limits for its growth in Dachigam, would be -8.7% (r=-0.087; SD, (r)=0. 137). The sensitivity analysis indicates a 25% chance of extinction in 100 years. The population will have a decrease in genetic heterozygosity over time. The probability of extinction (PE) for the Hangul population without (normal) and with a density dependent recruitment (den-dep-rec) population ranges between 3% and 4% in a scenario having 5 individuals (2 females and 3 males). Increasing the chance of poaching to 39% (cat-poach and cat-poach - woutdd) with additional winter mortality with a 5% chance of occurrence will substantially increase the extinction risk (cat-poach-winter and cat-poach-winter-woutdd) to 90%. The Hangul population needs an intensive monitoring programme to understand better the factors affecting the population growth.

Since the demographically and genetically viable population of Hangul is presently confined to the 41 sq. km area of the lower reaches of Dachigam NP, it is important to expand the range and habitat of the population to the 141 sq. km extent of Dachigam NP, including the alpine meadows of Upper Dachigam, by taking strict measures to make this area free of livestock grazing so that these ideal summer habitats recover and are used by Hangul in summer as it used to be in the past (Gee 1965; Schaller 1969; Iqbal 1986; Rahul Kaul pers. comm. in 2006). Livestock grazing in Upper Dachigam may prove harmful to Hangul in the long run. Apart from competition for food resources (Smith and Julander 1953), chances of transmission of disease also exist as there has been confirmed evidence of transmission of John's Disease to Hangul in Dachigam in 1978 (Inayatullah 1987). Parasitic investigations of 41 Hangul dung samples from Dachigam NP indicated considerable parasitic infestations of (25%) in the free ranging Hangul population. Recent research studies conducted in the Valley of Flowers NP (Kala *et al.* 1997) and Nanda Devi NP and Kedarnath Wildlife Sanctuary (Sathyakumar 1993, 1994, 2004) have shown that in livestock excluded areas the wildlife habitats have recovered extremely well and that populations of flora and fauna have increased.

A Hangul Species Recovery Plan is required to be initiated urgently. It should include field surveys to identify corridors to help the dispersal of the Hangul to its former distribution range and habitat protection in Upper Dachigam and other potential Hangul habitats outside Dachigam besides a conservation breeding plan for the Hangul to repopulate existing good habitats in the Hangul range. Overa WS and Shikargah Conservation Reserve, almost free from human interference at present, would be ideal locations to initiate Hangul reintroduction. These regions held a good population of Hangul in the past and do hold some stray animals (*c.* 6 individuals estimated in Overa and 7-12 in Shikargah)

today. Besides, these protected areas have diverse and ideal habitats similar to those of Dachigam and close corridor links with Dachigam NP. With the minimum of 10 Hangul which would be required for restocking in an area such as Overa WS, with an assumed carrying capacity of 100 Hangul, and supplementation of 4 more Hangul (2 males and 2 females, each 2 years old), there is a likelihood that the Hangul population will show a growth rate of 5.3% (r=0.053 SD, (r)=0.14) and the population will grow to 88 Hangul in the next 100 years in Overa WS.

However, the other areas of the Hangul's past distribution, such as the Erin catchments of Bandipora, Baltal-Thajwas WS, Tral Reserve, Desu *rakh*, Rajparyan (Daksum) WS and Kishtwar High Altitude NP, require special attention and immediate management and conservation efforts on scientific lines. Continued monitoring and surveys are required to be carried out in these areas for collecting baseline information on the habitat conditions and biotic interference in these areas *vis-à-vis* the present status and distribution of the Hangul, if any. These data could then be interpolated to assess the re-establishment of these areas as well as corridors for Hangul and reintroduction.

Continued examination of the perceptions and the opinions of the local people living near Dachigam NP and adjoining reserves and erstwhile stronghold areas of the Hangul are necessary for perpetuating an effective long term strategy and a conservation and management recovery plan for the Hangul and its habitats, including an *ex situ* conservation breeding programme.

ACKNOWLEDGEMENTS

We are thankful to the Government of Jammu & Kashmir and the Ministry of Environment & Forests, Government of India, for sponsoring this research study after a gap of more than 15 years after insurgency broke out in the state of Jammu & Kashmir in 1989. Special thanks are due to the Chief Wildlife Wardens of the Jammu & Kashmir Government, Regional Wildlife Wardens, Kashmir Region, and Wildlife Wardens, Central and South Divisions, for their support, encouragement and kind cooperation throughout the study period. We thank the Directors of the Wildlife Institute of India, Dehradun, their colleagues and staff of different divisions for their help, support and kind cooperation.

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WHEN *CHANOS CHANOS* BECAME *TSUNAMI MACCHI*: THE POST-DECEMBER 2004 SCENARIO IN THE ANDAMAN & NICOBAR ISLANDS

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The earthquake that triggered the tsunami of December 26, 2004, also caused a significant and permanent shift of the lay of the Andaman and Nicobar Islands. The northern Andaman Islands saw a lift of up to 1.5 m, while the Nicobars, in the south, subsided in places by nearly 4.75 m. This resulted in much larger damage caused by the tsunami to life and property in the Nicobar Islands even though the area and population here are much less than those in the Andamans. Huge changes were also effected to the topography of the islands and the coastal and marine ecosystems.

An intriguing set of subsequent and successive changes in the disturbed ecosystems have also started to occur, but little is being done to study or understand these. These changes, as also the continued seismic activity in the region, are important determinants that need to be kept in mind for reconstruction and rehabilitation efforts, and for future policy and development planning in these islands.

Key words: Andaman & Nicobar Islands, earthquake, tsunami, December 26, 2004, ecological changes

INTRODUCTION

The Andaman and Nicobar Islands are a chain of 572 islands, reefs and rocks in the Bay of Bengal. The total distance between the extremities is about 355 km, whereas the maximum width is 60 km. The islands are the summits of a submarine range of hills 1,120 km long that connect the Arakan Yoma of Myanmar with the Achin head of Sumatra (Anon 2003). The total area of the island chain is 8,249 sq. km[1] of which the larger and more numerous Andaman group of islands cover 6,408 sq. km, while the southern group of the Nicobars cover 1,841 sq. km (Saldanha 1989).

According to the census data, the total population of the Andaman and Nicobar Islands was 3,56,152 in 2001. Of this the population of the Andaman islands was 3,14,084 and that of the Nicobars was 42,068[2].

The Earthquake and Tsunami of December 26, 2004

The earthquake of December 26, 2004, and the tsunami that came in its wake are the greatest disaster to have hit the Andaman and Nicobar Islands in living memory (Malik and Murthy 2005). This is not surprising considering the fact that Indira Point, the southern most tip of the islands, located on Great Nicobar Island (6° 45.2' N; 93° 49.6' E), is only about 180 km from the epicentre of the earthquake that triggered the tsunami. Official figures list 3,513 people as either dead or missing and 7,992 hectares[3] as the paddy and plantation land that was affected. A total of 938 boats were fully damaged, while the number of livestock reported to have been lost in the disaster is 1,57,577 (Anon 2006; Chandi n.d.).

Disaggregation of these figures along the lines of the two island groups gives a very interesting and important picture. Of the 3,513 people reported dead and missing, only 64 are from the Andaman group of islands, the remaining 3,449 being from various islands in the Nicobar group. Of the total agricultural and paddy land destroyed, 76% is from the Nicobar group. Similarly, 80% of livestock loss was in the Nicobars. The latest figures for houses being constructed for the tsunami affected also indicate a similar trend. Of the 9,797 permanent houses being constructed, 7,001, or 71%, are in the Nicobars (Table 1).

It is evident that the impact in the Nicobar group of islands was much worse than that in the Andaman Islands. So, while the Nicobar Islands account for only 22% and 12% of the area and population, respectively, of the entire chain of islands, 98% of the deaths and 76% of loss of agricultural land occurred here. The damage caused is inversely proportional to the area and population of the two groups and strikingly so (Table 2).

While the tsunami was directly responsible for most of the damage, a more fundamental explanation lies in the earthquake that caused the tsunami. While the tectonic movements triggered by the earthquake catalysed the tsunami, they also caused a huge and permanent shift in the lay of the

[1] It is important to bear in mind that these are pre-December 2004 figures. The latest figures are not available.

[2] The estimated total population for the island group in 2009 was 475,000.

[3]A subsequent statistic from the A&N administration indicates that the total agricultural land lost was 10,837 hectares, of which 9,107 hectares was said to be plantation land and 1,730 hectares was paddy land. The island-wise break-up for this figure is not available.

Paper read at the International Conference on 'Conserving Nature in a Globalizing India' at Bengaluru; February 17-19, 2009

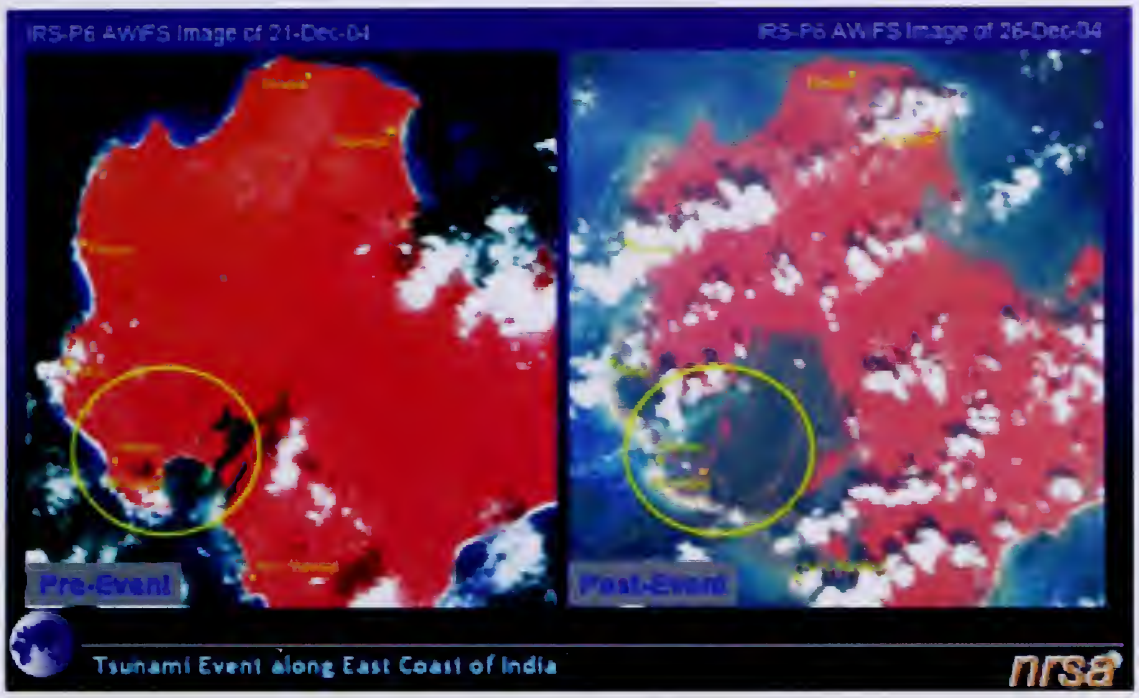

Fig. 1: Satellite images of Katchall island before (left) and after (right) the earthquake of December-2004

Table 1: Island-wise losses

	People (dead or missing)		Livestock loss		Agricultural land lost		Permanent housing		Area		Population (2001)	
	Total number	%	Total number	%	Area in hectares	%	Number	%	Sq. km	%	Number	%
Andamans	**64**	**2**	**31,521**	**20**	**1,877**	**23.5**	**2,796**	**28.6**	**6,408**	**77.68**	**3,14,084**	**88**
South Andaman			19,634		1667		823					
Little Andaman			11,165		117		1,973					
Middle Andaman			722		93							
Nicobars	**3,449**	**98**	**1,26,056**	**80**	**6,115**	**76.5**	**7,001**	**71.4**	**1841**	**22.32**	**42,068**	**12**
Car Nicobar	854		50,350		969.35		3,941					
Chowra	117		11,896		230.4		346					
Teressa			17,307		743.96		506					
Katchal	1,551		18,678		1,628.50		315					
Nancowry	378		1,440		256.57		269					
Kamorta			7,501		637.4		518					
Trinket			2,590		328.5							
Little Nicobar			2,267				111					
Great Nicobar	549		12,298		1,291.28		995					
Kondul			336									
Pilomilow			823									
Bambooka			570		29.55							
Total	**3,513**	**100**	**1,57,577**	**100**	**7,992**	**100**	**9,797**	**100**	**8,249**	**100**	**3,56,156**	**100**

Andaman and Nicobar Islands. Preliminary reports and assessments show that with a pivot figuratively and roughly located near Port Blair, the Andaman Islands, in the north, experienced a permanent uplift of 1-2 m, while there was a subsidence of up to 4 m in the Nicobar group of islands (Bilham *et al.* 2005; Malik and Murthy 2005; Ramanamurthy *et al.* 2005; Thakkar and Goyal 2006)[4] (see Web link in reference for map; also see attached maps (Figs 1 and 2) from the

[4]Also see http://cires.colorado.edu/%7ebilham/IndonesiAndaman2004_files/AndamanSRL4Mar.htm and (downloaded 10/08/2010) and http://dsc.nrsc.gov.in:14000/DSC/Tsunami/CaseStudies.jsp?state=ANDAMAN_NICOBAR%20ISLANDS# (downloaded 10/08/2010)

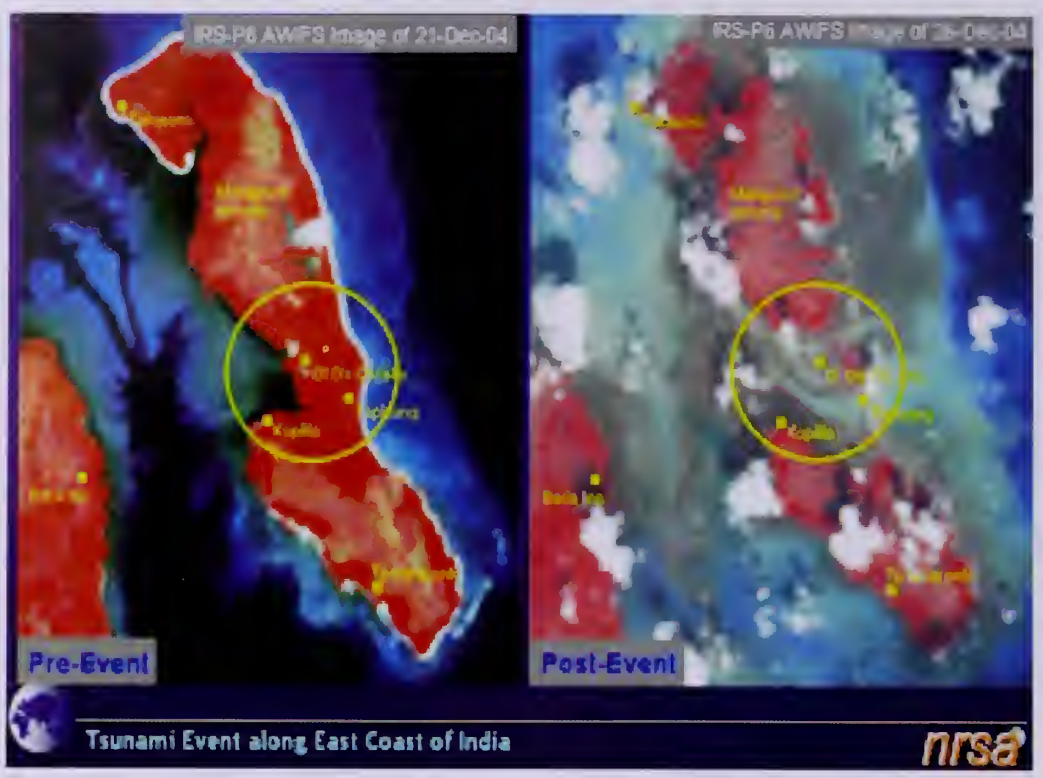

Fig. 2: Satellite images of Trinkat island before (left) and after (right) the earthquake of December-2004

National Remote Sensing Agency (NRSA)). The tide gauge at Port Blair is reported to have recorded an initial subsidence of the harbour (or rise in sea level) about 38 minutes after local shaking commenced (op. cit.). Eyewitness accounts indicate that the main shocks were felt in Port Blair around 0635 hrs IST on December 26, 2004. While this was followed almost immediately (15-20 minutes later) by the first influx of sea waves, it was around 0830 hrs, 2 hours after the main shock, that a third wave hit the shores with a velocity that caught citizens unaware (Anon 2005b).

Other reports (http://www.asce.org/files/pdf/tsunami/3-7.pdf) indicate that there was a gap of 50 minutes between the initial earthquake and the first wave of the tsunami in Port Blair. Three more waves are reported to have followed with a gap between each other of 30-35 minutes. While there is no information to indicate what may have happened in other parts of the islands, it can perhaps be assumed that the pattern everywhere was the same and, by implication of importance and significance, that the subsidence and uplift of the landmass occurred before the most powerful and damaging of the tsunami waves hit the shores of the Andaman and Nicobar Islands. The Nicobars, though spread over a smaller area and also more thinly populated, suffered much greater damage than did the Andamans as a consequence, and this is reflected in the figures of those killed during the tsunami and of agricultural and horticultural land lost.

The dominant human population in the Nicobar Islands is the Nicobari tribal community, which is essentially coastal dwelling (Singh 2006). They were therefore the most

Table 2: Island-wise losses as percentages

	Andamans (%)	Nicobars (%)	Total
Area (sq. km)	6,408 (77.68)	1,841(22.32)	8,249
Population (2001)	3,14,084 (88)	42,068 (12)	3,56,152
People (dead or missing)	64 (2)	3,449 (98)	3,513
Livestock loss	31,521 (20)	1,26,056 (80)	1,57,577
Agricultural land lost (hectares)	1,877 (23.5)	6,115 (76.5)	7,992
Permanent housing	2,796(28.6)	7,001 (71.4)	9,797

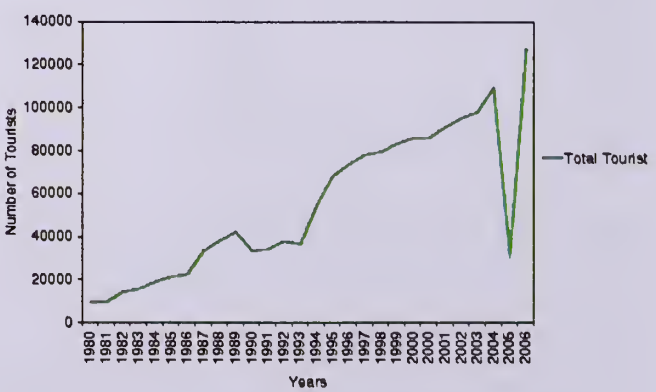

Fig. 3: Tourist arrivals in the Andaman Islands

vulnerable and in the direct route of the powerful tsunami which followed the significant subsidence that took place on account of the earthquake. Of the 3,513 people reported dead or missing, a full 2,955 were from the tribal community (Anon 2006).

ECOLOGICAL CHANGES

The Nicobar Islands

Significant changes were reported along the coastline of most of these islands. The small Megapode Island, located west of Great Nicobar, has, for instance, gone completely under (Manish Chandi, pers. comm.). Coral reefs, beaches and low lying coastal forests across the Nicobars were badly affected. The Nicobar reefs were hit due to the combination of the submergence, the resultant increase in turbidity and the physical damage caused by the tons of debris thrown back and forth by the furious waves. A survey conducted by the Zoological Survey of India reported large scale sedimentation on coral reefs around Great Nicobar Island after the tsunami. A reduction in the number of other associated coral reef fauna including nudibranchs, flat worms, alpheid and mantis shrimps, and hermit and brachyuran crabs was also reported (Alfred *et al.* 2006).

In an interesting development immediately after the tsunami, fishermen from Campbell Bay, in Great Nicobar, reported a sudden and huge increase in the catch of Milk Fish *Chanos chanos*, which was relatively rare earlier. So huge and sustained was the harvest of this particular fish that it quickly came to be called the 'tsunami *macchi*' (Anon 2005a). While the exact causes can only be speculated about, a post-tsunami ocean salinity and temperature study carried out in the islands by scientists of the National Centre for Antarctic and Ocean Research did find a considerable thermohaline variability in the upper 300 m column of ocean water and concluded that changes such as this could be expected to have a significant impact on primary production and fisheries (Luis *et al.* 2007).

Early surveys conducted by the Andaman and Nicobar Environment Team (ANET) in the Nicobars also indicated huge losses of Pandanus *Pandanus leram* and the Nypa Palm *Nypa fructicans*. The Nypa Palm in particular was wiped out almost completely from the estuarine regions of Little Nicobar and Great Nicobar islands. Significantly, both these plants are extremely important for the Nicobari community as a source of food and materials for regular use, such as for thatch for their dwellings. An effort is now being made with the help of the local communities to repopulate these islands with these very important and useful species (Chandi 2005a,b, 2006).

The permanent submergence in the Nicobars also saw the immediate and complete loss of most of the beaches here, many of which were important nesting sites for the 4 marine turtle species found here — the Giant Leatherback *Dermochelys coriacea*, the Green Sea Turtle *Chelonia mydas*, the Olive Ridley *Lepidochelys olivacea* and the Hawksbill *Eretmochelys imbricata*. This change, however, was a short-lived one, and new beaches had started to form along the altered alignment within months. Nesting turtles too were back again very soon (Murugan 2006; Chandi *et al.* 2006).

The damage to the low lying coastal areas, the coastal forests and the mangroves, however, was more permanent. Large tracts of the forests were completely destroyed, and for many months after the disaster the islands in the Nicobars could be seen encircled by an endless brown wall of dying and decaying trees. A remote sensing and GIS based study of the Central Nicobar group of islands (Nancowry, Camorta, Trinket and Katchal) by the Institute for Ocean Management at Chennai's Anna University has assessed the damage to range from 51% to 100% for mangrove ecosystems, 41% to 100% for coral reef ecosystems and 6.5% to 27% for forest ecosystems (Ramachandran *et al.* 2005).

Dr. Ravi Sankaran of the Sálim Ali Centre for Ornithology and Natural History (SACON) conducted a rapid impact assessment of the Nicobars almost immediately after the disaster. His main interest was to look at the status of the Nicobari Megapode *Megapodicus nicobariensis nicobariensis* and *M.n. abbotii*, the ground nesting endemic bird that scrapes together a mound of earth as a nest in low lying coastal forests. The submergence in the Nicobars had permanently destroyed a huge part of the bird's nesting habitat, and the study found that nearly 1,100 nesting mounds had been lost (Sankaran 2005).

A subsequent survey in early 2006 by the Wildlife Institute of India covered nearly 110 km of the coastline in 15 islands in the Nicobar group. The study estimated that only about 500 active nesting mounds of the bird had survived in the Nicobars and that the megapode population post-tsunami was less than 30% of what had been estimated during surveys conducted nearly a decade ago (Sivakumar 2006). While the bird has certainly been hit badly, the impact is not as bad as was initially feared.

Little is known, however, of the other equally vulnerable, coastal forest dwelling fauna, prominently, the Giant Robber Crab *Birgus latro*, the Reticulated Python *Python reticulatus* and the Malayan Box Turtle *Cuora amboinensis*. There is almost no idea of how these have been impacted, and there are indications that these have come worse off than the megapode.

There were initial fears, particularly in the case of the Giant Robber Crab that it might have become locally extinct in the Nicobars as it inhabits that section of the coast that was

most badly devastated – the less than 100 m wide strip of forest adjacent to the sea. There were reports however that they were being occasionally sighted and this was confirmed when four individuals – two on Camorta Island and one each on Great Nicobar and Menchal were sighted in late 2006 (Patankar 2007).

The Andamans

Areas around Port Blair also experienced permanent submergence (about 2-3 feet) and saw a fate similar to that of the Nicobars. The damage is most clearly seen in the low lying area of Sippighat, just a few kilometres outside the capital town. Mangrove marshes that had been converted to paddy fields over many years were permanently submerged and lost. A study conducted by scientists of the Port Blair based Central Agricultural Research Institute (CARI) found a severe impact on mangroves in the creeks of Sippighat, Shoal Bay, Chouldhari and Mahatma Gandhi Marine National Park at Wandoor, due to high salinity stress and permanent inundation (Dam Roy and Krishnan 2005). As in the case of Great Nicobar, this led to one dramatic, though short lived, change here. For the first few months immediately after the tsunami, Sippighat Creek became a huge production ground for the best prawns that residents of Port Blair had ever eaten (pers. obs).

Most of the other parts of Andamans, however, experienced a fate that was the opposite of that of the Nicobars and of what was seen near Port Blair. The CARI study found, for instance, that the mangrove stands of Deshbandhugram, Laxmipur, Milangram and Swarajgram, in North Andaman, remained exposed even during high tide. Sea water was not reaching the mangroves at all, and within a few months of the event they had started to wilt (Dam Roy and Krishnan 2005).

The most dramatic impact, however, was seen off the west coast of the northern part of the Andaman Islands. Huge areas of coral reefs were permanently thrust above the high tide line, destroying them within weeks. A rapid assessment of the Andamans carried out by the Andaman and Nicobar Environmental Team (ANET) 2 months after the earthquake estimated that more than 50 sq. km of coral reefs had been so exposed and killed – the largest area being nearly 25 sq. km, west and north of Interview Island (Andrews and Vaughan 2005). A similar impact was seen in parts of Indonesia too. The coral reef damage due to the tsunami was nominal in comparison to that which happened on account of the earthquake. "The most dramatic damage to Aceh reefs," says a report by Living Oceans, Reef Check and IUCN, "was also caused by the earthquakes. Hectares of reef flat at Pulau Bangkaru Island and Simeulue were uplifted to a level above the high tide mark resulting in total mortality of previously healthy and intact reefs" (Foster *et al.* 2006).

The situation for the sea turtle nesting beaches appears to have turned up a mixed bag in the islands. Flat Island, a small island on the west coast of the main Andamans, for instance, was an important sea turtle nesting site prior to the tsunami. The uplift caused by the earthquake has exposed coral reefs surrounding the island and now created a barrier to sea turtles visiting the island to nest. Some beaches such as those in Little Andaman Island are reported to have become wider, and the gradients have also become gentler due to the tectonic activity (Chandi *et al.* 2006). The ANET team also reported extensive damage to sea grass beds, something that was evident by the many weak Green Sea Turtles and dead specimens that were seen in many places during the surveys they conducted.

CONCLUSION

The islands have always been very active seismically (Rajendran *et al.* 2003), and there is evidence now that the sensitivity and activity have increased since December 2004. Nearly 20 earthquakes of a magnitude over M6 in addition to several hundred of lesser intensity have been recorded in the region after December 2004 (http://earthquake.usgs.gov/regional/world/historical_country.php#indian_ocean).

Some, such as the September 12, 2007, earthquake off the Sumatra coast of a magnitude greater than M8 on the Richter scale resulted in a tsunami warning being issued in the Andaman and Nicobar Islands as well (Raju 2007).

Increased seismic activity and the increased threat on account of this need to now be made an important aspect of policy and development planning in the islands. Similarly, the change in the topography of the islands on account of the tectonic movements caused as a result of the massive earthquake of December 26, 2004, needs to be factored in, both for the ongoing relief and rehabilitation work here and for future planning.

An important illustrative example would be the tourism industry in the islands and its aggressive promotion post-December 2004. The industry has been promoted as an important revenue earner and employment creator for people in the islands. A lot of financial resources are also being spent to encourage tourists to come to the islands, and special packages for government employees have also been created.

A study led by the NGO EQUATIONS (Anon 2008), however, shows that the contribution of the tourism industry to the economy of the islands is extremely nominal. The contribution of tourism in the islands to the Gross State Domestic Product (GSDP) has been stagnant at around 8% for the last 2 decades though tourism arrivals themselves have

grown by about 1,000%. Further, its contribution to revenue generation is also insignificant. Tourism (as in the hotels and restaurants sector) was found to employ less than 1.5% of the total main workforce of the islands, and this employment is seasonal. It is well-known that tourism is an extremely fickle industry and is affected adversely and almost immediately by other factors such as natural disasters, political strife or economic fluctuations. Figures for tourist arrivals (see Fig. 3) to the Andaman Islands provide an excellent indication of this as numbers fell to almost nil immediately after the tsunami. Creating exclusive reliance on such an industry for stimulating economic growth and employment is bound to fail.

There is an urgent need also to re-calibrate the high tide line (HTL) across the islands to allow correct implementation of the regulations related to coastal management and development. This has implications for development planning, location of construction projects, including those for tourism, and ensuring protection of the coast as per the laws and policies of the land.

As far as the ecological changes are concerned, observers (Andrews and Vaughan 2005; Sankaran 2005) have argued that no drastic interventions should be made to "correct" the situation. They have argued that no intervention would be the best intervention and the processes of nature should be allowed to take their own course.

An understanding and incorporation of these aspects should be made fundamental to dealing with the present and future situation in the A&N islands. That would be the first step towards dealing with existing and future vulnerabilities. Ignoring these and the implications is only an invitation to more trouble in the future, with potentially disastrous consequences.

ACKNOWLEDGEMENTS

I would like to thank all my colleagues at Kalpavriksh for their continued interest and support for my work in the Andaman and Nicobar Islands. I would also like to thank the entire team at the Andaman and Nicobar Environment Team — Harry Andrews, Manish Chandi, John, Agu, Nelson, Naveen, Uncle Pao, Uncle Pambwe and Montu. Thanks also to the team at EQUATIONS, in particular to Rosemary Vishvanath and Syed Liyakhat.

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PITFALLS AND OPPORTUNITIES IN THE USE OF MARKET-BASED INCENTIVES FOR BIODIVERSITY CONSERVATION

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Market arrangements fail to capture the range of benefits provided by conservation because of their public goods nature. In consequence, biodiversity is routinely undervalued and overexploited. A variety of instruments and payment schemes have been developed to help finance conservation by capturing these non-marketed benefits. This paper reviews market-based approaches identifying the salient features which determine their potential for improving conservation finance.

Key words: Market-based Instrument, Payment for Ecosystem Services, biodiversity conservation, environmental decision making

INTRODUCTION

Market-based mechanisms have taken a respected position among the tools for achieving both conservation and broader environmental objectives. The title of the reports, "Harnessing Market Forces to Protect the Environment," (Project 88 Conference 1989) and "Harnessing Markets for Biodiversity" (OECD 2001) are suggestive of the expectations placed on the power of market forces to achieve environmental goals. Other titles on the subject, such as "Silver Bullet or Fool's Gold," (Landell-Mills and Porras 2002) suggest that more circumspection is necessary before wholesale acceptance of market-based mechanisms as tools of biodiversity conservation. Market-based mechanisms are based on the market forces of supply, demand and trade. They rely upon price-type signals and trading among agents responding to economic opportunities, such as increased incomes or lower costs. Instruments considered to be "market-based" include:

1. Price-based instruments, such as taxes for undesirable behaviours, such as habitat degradation, pollution or species takes, fees, and penalties;
2. Price-based instruments, such as subsidies, to reward desirable behaviours, such as maintenance of land under forest cover, debt-for-nature swaps and conservation easements;
3. Price-based liability approaches such as deposit-refunds and performance bonds;
4. Quantity-based instruments involving market creation and trading of responsibilities, such as wetland mitigation banks, carbon credits, fishing permits and land development rights;
5. Demand enhancements and information disclosure, such as eco-labelling, and certification.

The first and perhaps most important surrounding the use of market-based incentives is that, from an economic perspective, environmental problems have traditionally been explained as results of market failure or the absence of markets. The market failure perspective poses several questions that are not answered satisfactorily by the conventional economic approach to environmental problems.

- First, when and how is it possible to transform the problem setting under interest so that quasi or real markets can be created where none existed before?
- Second, what economic, distributive and governance advantages or disadvantages do market-based instruments offer in comparison to government-centered regulatory solutions or public supply?
- Thirdly, what is the full range of market-based solutions that are applicable for conservation?
- Fourthly, what are the key issues that determine which market-based solutions can be expected to support conservation?

The purpose of this paper is to address these questions and consider the role that market-based instruments can play in achieving conservation objectives. While there certainly may be opportunities, there are also pitfalls that must be avoided in implementing these instruments for conservation.

1. Market failure versus ecosystem services as the basis of conservation transforming the problem setting

Conventional welfare economics suggests that environmental problems are caused by the absence of markets or by market failures such as externalities, public goods, and

Paper read at the International Conference on 'Conserving Nature in a Globalizing India' at Bengaluru; February 17-19, 2009

imperfect information. This public goods element to environmental problems has suffered from consistency problems. Some scholars have defined public goods as goods that are provided publicly, others have underlined the difficulty of excluding unauthorized users as their hallmark, and still others have rightly associated public goods with non-rival or joint consumption. The lack of excludability and rivalry in consumption provides an incentive for consumers to free ride and disincentives to potential providers who are unable to exclude unauthorized users. From an efficiency point of view, this results in too high or low level of an environmental impact or service, and a corresponding suboptimal allocation of environmental resources. Conventional solutions have relied predominantly on command and control measures or the public provision of public goods.

In terms of externalities, conventional theory portrays environmental problems as unwanted side-effects of otherwise beneficial economic activities. It then suggests a narrow range of government-centered policy responses such as regulations, forgetting that government intervention is not always needed to resolve externality problems if agents can bargain with one another (Coase 1960; Cheung 1973). There is evidence that many jointly consumed or high exclusion cost goods have successfully been provided privately (Coase 1974) or communally (Ostrom 1990). Therefore, there may exist alternative working governance solutions which have been overlooked by the dominant policy paradigm.

An alternative framework for addressing environment/economic interactions stems from the view that biodiversity and ecosystem services play a fundamental role in sustaining all human activity, and that well-functioning ecosystems are germane to human welfare. The concept of ecosystem services has its roots in ecology, but many ecological economists have made it a starting point for their economic analysis. Ecosystem services can be defined as "the benefits humans receive, directly or indirectly, from ecosystems" (Costanza *et al.* 1997; Farber *et al.* 2006) or as "the end products of nature that yield human well-being" (Boyd and Banzhaf 2005). Ecosystem services are generated by ecosystem functions, such as regulation, habitat, production and information, which in turn are underpinned by ecosystem structures and processes (de Groot *et al.* 2002).

Ecosystem services are of unquestionable economic relevance. Costanza *et al.* (1997) have estimated that the value of the world's ecosystem services is at least $ 33 trillion annually. Balmford *et al.* (2002) have demonstrated that nature conservation often generates higher economic returns than intensive use of natural systems, which entails their conversion (Turner *et al.* 2003; Naidoo and Adamowicz 2005). A vast amount of more narrowly focused valuation research exists. However, natural systems should not be valued only in terms of the benefit streams they generate. Natural systems provide life support services and have "glue value", because they constitute the infrastructure without which the provision of ecosystem services would not be possible (Turner *et al.* 2003).

Ecosystem services' thinking has undoubtedly broadened possibilities for supporting biodiversity conservation. Ecosystem service approaches are steadily gaining currency in policy spheres with a number of recent governance reforms being either directly underpinned by such an approach or compatible with it. For example, the European Union's Habitats and Water Framework Directives create multi-level governance solutions with jurisdictions that respect spatial aspects of the pertinent resources. These governance solutions also recognise a range of user groups and involve them in planning and decision-making processes. The support of environmental protection measures under the European Common Agricultural Policy (CAP) in turn commissions ecosystem services from private providers. These payments for the provision of ecosystem services are not subsidies: they are prices paid for the provision of services to private providers, who own and control environmental assets such as forests, pastures, or agricultural land.

In recent years, lack of information or information asymmetries between potential market participants has come to seen as a further reason for missing or inefficient markets. For markets to develop in conservation related services, one set of required information is understanding the functioning of ecosystems and ecosystem services, their dependence on land cover or use and metrics for measuring service delivery over baselines. Recognition, and identification, and better scientific understanding of ecosystem services have therefore led to more voluntary, Coasian type bargains, between private parties.

Nestlé, which owns the natural mineral water sources of Vittel in France, protected the spring catchment area, which had been intensively farmed (with resulting nutrient run-off and pesticide residues), by purchasing and reforesting the catchment. It further reduced non-point pollution by signing 18-to-30-year contracts with the local farmers to reduce nitrate pollution (The Economist 2005). In 1998, a hydroelectricity company signed a voluntary agreement to pay a local NGO, the Monteverde Conservation league for the water-based services provided by the forest they own (Reyes *et al.* 2002). In the Philippines, a hydroelectric company also provides incentives to local communities for reforestation of a water catchment (Mero 2002). Conservation easements and land trusts are also examples

of self-organized private deals between organizations and landowners whereby a conservation or protection arrangement is privately negotiated and purchased.

2. What economic, distributive, and governance advantages or disadvantages do market-based instruments offer in comparison to conventional government-centered solutions such as regulation and public supply?

The choice of governance and institutional arrangements in the management or delivery of services affirms or redefines entitlements to environmental resources, and has thus both efficiency and distributive consequences. Choices between different instruments for biodiversity conservation are primarily about the distribution of wealth and income, and about the realization of sought-after conservation outcomes.

Characterizations of environmental policy instruments commonly distinguish between "command and control" measures and "market-based" measures. Command and control measures include a wide range of environmental regulations, binding environmental plans, and procedural requirements.

The common feature of both categories of policy instrument is the creation of entitlements to ecosystems or ecosystem services. Environmental regulations are often viewed purely as constraints but they do create entitlements (albeit non-transferable ones). Regulations that prohibit the use of substances such as DDT, or the taking of an endangered species, create the entitlement to be free from the adverse consequences of these actions. Similarly, the conditions of pollution permits issued under the US's Clean Water Act, vest in the polluter conditioned entitlements to the capacity of water courses to assimilate wastes. Such entitlements are less explicit than in the sphere of market-based instruments where there has been a better understanding of how they create transferable entitlements, which facilitate their exchange.

Conventional wisdom has it that compared to command and control measures, market-based instruments are better at achieving environmental objectives at lower cost to both industry and society. This is due to the ability to transfer responsibilities across parties, as in the case of tradable permits, and the incentives created by some instruments for parties to reduce environmental management costs through introduction of better technologies and practices. Evidence from pollution control programs supports this view. The US Acid Rain program used a trading scheme to reduce emissions of sulphur dioxide. The resulting market was estimated to have resulted in cost savings of $1 billion annually compared to the expected costs under a command and control approach (Stavins 2001). Some have argued that command-and-control regulations are not necessarily worse in this respect and caution against a blanket prescription for market-based approaches (Porter and van Linde 1995). Some authors argue that such approaches are more suited for the institutional context of modern nations, rather than developing countries (Russell and Powell 1996).

The choice of instrument type is often a matter of distributive justice. For example, many agri-environmental schemes recognize transferable entitlements of farmers while industrial polluters are often regulated. The latter often have market power which enables them to share costs of improved environmental protection with their customers by raising prices. Farmers have a far weaker position to do so in the markets for agricultural produce, so are more cost-conscious. Distributive justice is an important issue for conservation of biodiversity in both the developing and developed world. If the costs and benefits conservation accrue unevenly to different groups, those left with the costs are hardly motivated to contribute to conservation.

A disadvantage of market-based instruments is that they are not good in guarding against irreversibilities or dangerous outcomes. It is noteworthy, however, that regulatory restrictions on activities and market-based instruments can be complementary. For example, restrictions can be used to prevent irreversible and dangerous outcomes, like safe-minimum standards, and market-based instruments can be used to induce effective outcomes that go beyond these limits.

3. The full range of market-based instruments applicable for conservation instruments

Table 1 provides a summary of policy instruments conventionally deemed to be market-based.

4. Price-based instruments, such as taxes, fees, and penalties, for undesirable behaviours

These incentives have in common the fact that there is some "price" placed on an undesirable or desirable behaviour. There may be legal distinctions between taxes and fees, fees interpreted as a price for services "received." How and where taxes or fees can be levied depends on statutory or judicial requirements. Penalties are a "price" placed on proscribed or prohibited behaviours, and are punishments for violating, for example, legal responsibilities.

4.1 Opportunities related to taxes, fees and penalties

These pricing instruments may be effective in circumstances where there is clearly something to place a price on and where payments are collectable. Thus, the most commonly used price-based conservation related instruments

Table 1: Summary of policy instruments conventionally deemed to be market-based

Type	Instrument	Definition
Price-based instruments for undesirable behaviours	Direct	a compulsory unrequited payment not proportional to the good or service received in return for that payment.
	Fees Penalties Input/ output taxes	Price paid in remuneration for specific services.
Price-based instruments to reward desirable behaviours	Subsidies	an unrequited current payment for provision of a good or service.
	Indirect fiscal	fiscal incentives such as tax exemptions, capital grants, price guarantees and the provision of cheap credit.
	Payment for ecosystem services	A voluntary transaction in which an environmental service is bought by a minimum of one service buyer who, in return, compensates a minimum of one service provider, if and only if the provider secures that service.
	Conservation easements	A legal agreement between a landowner and another entity, that permanently limits land uses of the property in order to protect conservation values.
	Auctions	Competitive tendering process.
Price-based liability approaches	Deposit refunds	Monetary deposits paid by consumers at the time of purchase and returnable when items are returned.
	Performance bonds	Deposits required from extractive industries refundable if the payer fulfils certain obligations.
Quantity-based instruments	Cap and Trade	Markets in which established rights or allowances can be exchanged.
	Biodiversity offsets	Conservation actions intended to compensate for the residual, unavoidable harm to biodiversity caused by development projects, so as to ensure 'no net loss' of biodiversity.
	Tradable development rights	Rights to develop in conservation areas that can be sold for development rights outside a restricted area.
	Individual Tradable Quotas	Output/production controls that assign exclusive individual rights to harvest specific portions of an overall natural resource quota.
Product-based instruments	Ecolabels	Information systems for consumer products confirming the product has been produced in accordance with certain environmental standards
	Certification	Process of certifying claims made in relation to environmental standards.

include hunting, logging and fishing licenses, timber harvest taxes, export and import fees for traded flora and fauna, and protected area user fees. Timber harvest taxes are used in some developing countries although experiences with them have not always been encouraging (Kim *et al.* 2006). Timber harvest taxes should be based upon the full costs of logging

activities, otherwise there will be too much timber harvested relative to other uses of resources. These costs include not only direct logging costs, but also the costs of opportunities foregone, which may include the ecosystem services lost with forest conversion (Yaron 2001). With forestry, taxes to reduce harvesting could result in a wide range of ecological benefits in addition to just limiting biomass removal. Setting such taxes in a non-arbitrary manner is the key to using taxes for conservation. Knowing the ecological impacts of timber harvests, and evaluating those impacts in economic terms will be an important element in implementing such a tax.

Taxes are useful in resource use cases, where the behaviour is observable, there is something to tax, there is an identifiable agent to tax and property rights can be clearly established. If observation is difficult, punitive penalties may be the only meaningful deterrent, where penalties are set so high that they are extremely onerous if one is caught. Higher penalties must offset the higher likelihood that one will not be caught. Of course, the functioning of taxes is predicated on state capacity to collect taxes and to keep corruption at bay.

Taxes have been used in several developed countries such as the Netherlands, Sweden, and the United States to control nitrogen discharges from agricultural non-point sources. The primary motivations were to protect water quality and human health by such taxes, and also enhance riparian environments. Generally, an instrument will be more efficient the closer it is applied to the environmental damage but input taxes can be attractive instruments for controlling discharges from numerous non-point sources, because they entail lower monitoring and enforcement costs than other instruments, such as technological requirements. In Sweden, a tax of 0.2 Euros or about $ 0.25 per kilogram of nitrogen has reduced nitrogen utilization in agriculture by about 10 per cent (OECD 2001). Similar taxes have been introduced for pesticides. Although not common in developing country contexts, input taxes may have potential because they are relatively easy to implement with limited informational and institutional demands.

It is conceivable that the external costs of loss of biodiversity, associated with clearing native vegetation could be subject to tax but to date, such taxation has not been directly associated with conservation.

The tax system can be used to notionally capture willingness to pay for conservation in addition to making polluters pay for damage. Belize charges a tourist tax of $3.75 for each passenger arriving in country by plane or cruise ship, with the proceeds going to a national conservation trust that supports protected areas and other conservation activities. Costa Rica and other countries impose a tourism tax on the price of hotel rooms, some of which is earmarked for conservation. Fees are one of the easiest and most common price-based instruments for capturing willingness to pay and may cover access to protected areas or associated activities related to conservation (photography permits). Evidence suggest that fees charged do not always fully cover the willingness to pay of tourists attracted by nature (Naidoo and Adamowicz 2005)

4.2 Pitfalls

4.2.1 *Failure to define and assign property rights*

A critical requirement for price-based instruments is that the property rights associated with the "good or service" being priced are well-established and enforced. For example, setting a price on the degradation of wetlands will have no meaning if there is confusion about who "owns" the wetlands. The good or service that is priced must be clear, its units well measurable, and the rights well-established. These instruments will not work well where the institutions or cultural conditions are not conducive to establishing and accepting the concept of property rights.

4.2.2 *Behaviour must be observable and enforceable*

One precondition for the success of price-based approaches is that the behaviour be observable and capable of being monitored. This is not always the case; for example, in the enforcement of conservation easements in remote areas, or penalties for prohibited species takes or harvesting behaviour. Enforcement may be formal, such as monitoring by a resource agency, or informal, such as watchful citizens. The inability to adequately observe behaviour can lead to self interested agents avoiding compliance with contractual obligations. It can also lead to perverse effects such as the incentive to destroy an endangered species or habitat on one's property before it is discovered (Polasky and Doremus 1998; Lueck and Michael 2003). Developing countries, in particular, may have difficulty in collecting taxes or fees, and enforcing compliance with a price-based conservation system.

4.2.3 *Price incentives are most effective the more directly related to the undesirable behaviour*

The success of these incentives also depends upon the extent to which the "price" is directly related to the undesirable behaviour. While it may be more administratively convenient to levy the price on one behaviour, if this is not highly correlated with the undesirable behaviour, incentives are reduced and the instrument less effective. For example, suppose the sole conservation objective is to protect an endangered species from capture by humans; then a penalty levied on harm or harassment of a species would be the most

direct instrument. But suppose it is difficult or impossible to measure species harm directly. A second-best instrument may be a penalty for degradation of habitat associated with that species. This may still allow an agent to take the species by hunting even when the associated habitat remains undisturbed.

4.2.4 *Price incentives must be set at the proper margins of behaviour*

Price incentives must also be on the proper margins of behaviour to compel agents to respond in a desirable manner. For example, setting land development fees at a fixed rate independent of the level of land conversion creates fewer conservation incentives compared to a fee based on the amount of conversion. This is the same issue faced in designing fees for water use; a fixed fee may not induce consumers and firms to cut back on water use. The downside to pricing on the proper margins of behaviour is that agents may attempt to avoid the levies through undesirable actions; e.g., illegal habitat conversion or water theft. So, enforcement of the levies may require observing both legal and illegal behaviours.

4.2.5 *Prices must be set at the correct levels*

Setting prices at the correct level is another precondition for success. In general, if we want to see behaviour at a certain level, such as a number of acres remaining undeveloped, we must know what the cost of that behaviour is for agents in terms of the benefits foregone from not pursing alternative options. Then the prices must be set at a level somewhat in excess of that cost. If the price is set too low, it is cheaper for the agent to pay the tax, fee, or penalty, than to engage in the behaviour we seek to achieve. For example, if a landowner can obtain an additional income of $100 from some activity we would like to discourage, a price of at least $100 must be levied to discourage that behaviour. Unfortunately, we cannot always know these costs to agents. The more uncertain we are about agent costs, the more likely it is that prices will have to be altered to achieve acceptable outcomes. This problem arises because of imperfect information about the opportunity costs agents face and compounded by the fact that agents, whose behaviour we seek to change, may face very different opportunity costs for undertaking the same actions. Auction mechanisms are one means of addressing this informational asymmetry. If there is considerable likelihood that some behaviour could be especially deleterious, it may be more useful to simply proscribe the behaviour rather than use the more subtle pricing instrument. An example would be if it is absolutely critical to maintain a given area of wetlands for a critical conservation goal. Directly proscribing or prohibiting wetlands degradation may be more effective than using pricing instruments to ensure behaviour commensurate with the required habitat extent.

If pricing is based upon the benefits lost from some undesirable behaviour, a measure of these benefits must be established. For example, we must know the marginal value of wetlands services before we can set a benefits-based price on behaviours that degrade those services. This may not be simple. It may be easier to establish the cost to an agent for not engaging in the undesirable behaviour, suggesting that a cost-based price would be administratively easier.

When enforcement is uncertain, it is reasonable to consider setting prices at higher levels to account for the uncertainty. For example, suppose we wanted agents to effectively incorporate a price of $100 into their decision calculus before deciding to engage in some undesirable behaviour, such as dumping wastes into streams. But suppose there is only a 10 per cent chance that such behaviour will be observed by the enforcers. Then setting a price of $1000 would result in an expected price of $100 (10% x $1000). This is one of the arguments to assigning punitive damages; that enforcement is uncertain and it signals to other agents that the price of their undesirable behaviour will be high if they are caught. In this example, actual damages would be only $100, but the punitive damages would be $900.

4.2.6 *Uncertainty about expected benefits*

Another basis of pricing of behaviours is the benefits we expect to obtain when that behaviour is avoided. Under this interpretation, if the benefit of avoiding dumping into streams is $100, then setting the price at $100 at least allows recouping of damages. But if we do not know these benefits or they cannot be evaluated in monetary units, which is often the case, then setting a price based on benefits received is problematic. In such cases, reverting to prescriptive or proscriptive rules, such as permits or mandated actions, may be prudent.

4.2.7 *Agents must be responsive to the pricing instrument*

Another precondition for using these pricing instruments is that agents are responsive to these prices. It may be that agents are not highly rational, or do not make decisions based upon the same costs and benefits units as the prices. While pricing is perfectly general, i.e., the price can be monetary, or time, or chickens, etc., the prices may be in units that do not stimulate behaviour. The prices must have meaning. Monetary prices in a culture that is not highly monetized, or market oriented, may not be very effective. Also, there may be social reluctance to accept prices for things that were traditionally free.

4.2.8 *Inadvertent distributional consequences*

Such price-based mechanisms conform with the polluter pays principle with the statutory incidence of the tax falling on the polluter. The economic incidence of the tax may not. Depending in part on the elasticity of demand for the goods or services incurring the tax, businesses can pass on the tax in the form of higher prices for buyers, lower wages to workers or lower returns to investors.

5. Payments and Subsidies

Subsidies or payments for ecosystem services are the opposite of taxes, fees and penalties, and place prices on desirable behaviours. There is an important distinction between the two instruments. A payment for a service sets a price on the service, and agents can decide whether they wish to "sell" that service. A subsidy represents compensation to an agent for engaging in a desirable activity; the compensation can be direct or indirect, as in the case of tax breaks. The "pay for service" may have a different image to the public than the "subsidy for an activity." While subsidies are sometimes the cause of conservation problems, such as subsidies to the fishing industry that result in over-fishing (Myers and Kent 2001; Fujita *et al.* 2004) or agricultural subsidies that result in overuse of land, they can also be used to achieve environmental objectives. Payments for ecosystem services, where "producers" of environmental services (e.g., landholders whose forested land filters water) are compensated by "consumers" (e.g., downstream water users), are one such rapidly emerging mechanism. Despite their increasing popularity, these instruments do have pitfalls that need careful consideration. Payment systems include both fixed prices as well as auction-based prices.

5.1 Opportunities related to subsidies and payments

Subsidies and payments may be more effective than taxes, fees, or penalties in certain instances. For example, if an agent has the right to an activity, such as the right to develop land, subsidies or payments may be the only price-based instrument available to deter that activity under the initial assignment of property rights. This may be necessary in the case of species protection, as the legal battles in the US over the Endangered Species Act suggest. Paying people to save species rather than penalizing them if they do not may be a useful, albeit expensive, solution (Jenkins *et al.* 2004). Also, compensating persons who have been harmed as a result of conservation programs, such as farmers whose crops are damaged by preserving elephant herds, would increase the likelihood of harmed parties agreeing to the programs. It may be less costly simply to pay agents to do something rather than face what may be protracted legal costs.

Subsidies and payments may also be the most useful instrument when equity issues dominate a conservation objective. In many instances, conservation requires a few to bear the costs that benefit many. If this circumstance is viewed as too unfair, giving a subsidy may be more acceptable than a tax, fee or penalty. This may be particularly important in agriculture, as farmers are often viewed as being marginal economic enterprises.

Subsidy programs may offset costs to agents of engaging in conservation activities. Subsidies may be in the form of tax deductions or coverage of costs. For example, a Brazilian program, ICMS Ecológico, awards a share of national sales tax collections to municipalities if they engage in programs to establish restricted areas (Grieg-Gran 2000). This is presumably to offset the costs in lost revenues to municipalities from restrictions on land use and development. Ontario, Canada, has a tax incentive program for land conservation, whereby landowners can receive 100% property tax relief for preserving land in acceptable condition. Eligible lands include provincially "significant" wetlands, habitats for endangered species, and lands of natural and scientific interest. (http://www.mnr.gov.on.ca/MNR/cltip/).

The Environmental Stewardship program in England is a good example of a payment scheme (http://www.defra.gov.uk/erdp/schemes/es/default.htm). Farmers receive payments per hectare in return for accepting a package of management measures. Each management option receives a number of points, and the farmer is then paid based on the number of accumulated points. Points can be awarded based upon national or local significance and priorities. Since the program began in 2006, over 3 million hectares have been enrolled with 23,000 agreements and over £105 million have been paid.

In developing nations with weak regulatory and taxation systems, paying for ecosystem conservation may be one of the most effective ways to achieve conservation goals. The best known ecosystem service payment system outside of high-income nations is the one established by Costa Rica in 1995. The scheme was designed to enhance and sustain forested ecosystem services, including carbon sequestration, biodiversity, watershed management, and landscape beauty. The program pays landowners US$202/ha for forest protection, US$314/ha for sustainable forest management, and US$516/ha for reforestation (Miranda *et al.* 2004) for a contracted five years of protection. The state's National Forestry Finance Fund (FONAFIFO) purchases these services, then sells them to interested buyers. For example, it may sell carbon sequestration credits to international buyers, watershed management credits to national hydroelectric utility companies. So it is a hybrid purchase and trading program,

where the state is the trading agent.

Literature on information economics has forced policy makers to reassess policy mechanisms employed for many policy problems and has led to increasing interest in auction based approaches for publicly funded biodiversity programs rather than fixed price approaches (Stoneham *et al.* 2003). In negotiating biodiversity contracts, the conservation agency and potential participant will have varying information regarding the ecological worth of landholdings and on the opportunity costs of conservation. Auctions can help address this information asymmetry and potentially achieve greater conservation outcomes at lower cost than fixed payment schemes. The Australian Catchment Care program is an example of such an auction-based scheme to achieve cost-effective natural resource management actions (http://www.napswq.gov.au/mbi/round1/project26.html). In this recently developed program, landholders bid for contracts to establish conservation activities. These activities are scored on the bases of environmental value and threats. The score is then related to the proposed landholder cost; and proposed contracts are ranked on a cost-effective basis. Contracts are established for the most cost-effective bids until funds are exhausted or a reservation cost-effective price is reached. A full trial of the scheme was run in a watershed, where 29 bids were submitted, and 17 were selected for funding.

Another example of an auction-based payment scheme is the Bush Tender program in Australia (http://www.ecosystemservicesproject.org/html/publications/docs/Intro_to_MBIs_2005.pdf). Farmers proposed bids for projects that were then ranked by their biodiversity benefits. Winning bids were then selected based on their cost-effectiveness. Analysis of the program concluded that the auction approach delivered 25% more native vegetation for the same cost as a grants scheme.

The auction-based payment schemes are useful as they utilize competitive forces to achieve the most cost-effective conservation goals. However, they are administratively complex and require measurements of conservation outcomes, a task that may not be simple, depending on the outcomes desired. Useful measures of outcomes require more than just measures of land area impacted.

Payment schemes are not limited to government sponsored programs. Private agents may have sufficient incentives to pay for services useful to them. As noted, the Perrier-Vittel company, which sells bottled water, has financed reforestation and is working with farmers to develop less polluting management practices (The Economist 2005). In South Africa, a private ecotourism company, Conscorp, pays landowners to restore farmlands and stock them with native wildlife (Heal 1998). These are good examples of Coase's argument that government intervention may not always be necessary to manage externalities.

Both public sponsored and self organized deals have also created markets based on the establishment of property rights and the environmental aspects of assets, such as non-developed state of land. Development rights and other rights can be distinguished from other property rights and traded separately by using, for example, conservation easements.

Land trusts and conservation easements are widely used in the United States and elsewhere to pursue conservation goals. Land trusts purchase land for conservation or buy development rights or conservation easements on land which remains in external ownership. In Indiana, Sycamore Land Trust has been one flexible tool for attaining local conservation goals without the involvement of the state (York *et al.* 2006) and land trusts have also been used in the Mountain West for landscape and open space preservation (Booth 2002). However, land trusts allocate the costs of conservation to the public, which means that availability of funds will curtail the volume of conservation. Enforcement of easements in the courts can also be costly and the continuity of land trust depends on private donations. There is also a possibility of conflict between local and wider conservation goals and priorities.

Tradable development rights may be useful to achieve land-based conservation objectives. The initial assignment of rights is critical to the acceptability of this instrument, as is the question of who can buy these rights. Trading rules must be well-defined and administered, as these rights may be economically meaningful and contentious assets. These rights may be either in the form of tradable rights to develop, or as development "reduction" credits. Conservation groups may be given the right to purchase. As in the case of all these market-based instruments, monitoring and enforcement are critical to success. Assuring that development does not occur where proscribed may not be easy. For example, Brazil is allowing such trading under its general rule that requires landowners in the Amazon forest to maintain half of their land in forest (Jenkins *et al.* 2004).

5.2 Pitfalls related to subsidies and payments

5.2.1 *Property rights must be well-defined*

Altering behaviour is costly and these costs are the same to society whether subsidies (payments) or taxes (fees and penalties) are used to alter behaviour. The type of price used, subsidy or tax, defines property rights in status quo and determines who bears the cost of that change. Taxes leave the cost to private agent while subsidies redistribute the cost in part or in whole to the public. The argument for just compensation in takings is also based on the fairness issue of

who should bear the cost of an action.

5.2.2 *Political difficulties*

Subsidies may face political difficulties, as they may be viewed as paying agents to do something they should already be doing according to local norms or customs. For example, paying someone to stop using land in a certain way may be seen as implicitly sanctioning a use that was formerly taboo. Payments for actions may be viewed as more acceptable; even the terms "subsidy" and "payment" have different connotations.

5.2.3 *Financial limitations*

Subsidies and payments require funds to finance or can result in the loss of government revenues in the case of tax breaks. Financial limitations may restrict the use of subsidies.

5.2.4 *Permanence of outcome*

Related to financial limitations is the issue of permanence, a factor which must be considered when assessing appropriate mechanisms for biodiversity or ecosystem services. Assume a farmer is paid, through auction or subsidy, to fence off a stretch of native vegetation. When payments cease, she allows her cattle to graze the area, so that most of the benefits of biodiversity conservation will be lost. With water quality, in contrast, the benefits from the service of water purification will have been enjoyed throughout the contract.

5.2.5 *Perverse incentives*

Subsidies and payments can create perverse incentives. A subsidy or payment to avoid an activity may induce agents to engage in more of that activity. For example, paying agents to cease polluting a stream may cause them to want to increase proposed discharges in order to obtain higher subsidy payments. Subsidies and payments may also encourage entry and delay exit from an industry, exacerbating the original conservation issue. This latter issue is most likely to be a problem when the most inefficient firms/farmers are also the most environmentally damaging.

5.2.5 *Equity considerations*

In the Costa Rican example above, it is only farmers with property rights to land who can be paid for conservation.

5.2.6 *Costs of monitoring and enforcement*

Payments and subsidies are paid for taking specific actions, such as adhering to a specific land management plan, building storage capacity for manure, or setting land aside from cultivation. Their effectiveness depends on the ability to monitor compliance with applicable conditions and on the enforcement of these conditions. In many cases monitoring of compliance and enforcement are costly, which means that implementation and outcomes can fall short of the goals.

6. Deposit refund instruments

Deposit-refund instruments are specialized types of pricing instruments. Typically, a deposit is paid up front for an item or action, and a refund is given upon completion of some desirable action, such as return of the item or meeting some action criterion. Performance bonds require an up-front liability and, if the terms of environmental management are satisfied, the liability disappears.

6.1 Opportunities related to deposit refund instruments

Deposit-refunds on hazardous materials, such as oil and batteries can be helpful in reducing disposal risks and can therefore have a minor role to play in enhancing conservation. Performance bonds can play a more important role in achieving conservation or remediation objectives. These bonds are used in the US to secure funds to meet surface mining reclamation requirements. The mining company Gold Field's 2003 Annual Report noting that in Ghana, it funds environmental rehabilitation costs by posting a US$3 million reclamation bond, while in Australia, it guarantees its environmental obligations by providing the western Australian government with unconditional bank-guaranteed performance bonds to the amount of AUS$12.3 million. Whether such bonds are large enough, or remediation objectives are actually met are serious questions for the use of these instruments. For example, the state of Pennsylvania has had mining reclamation bonds in place for a long time, but the costs of acid mine drainage remediation have dwarfed the bond fund, leaving the citizens of the state with major unfunded cleanup costs. Bonds could be used to assure proper timber practices, as a pre-condition for wetlands development or as a condition for receiving a fishing permit.

6.2 Pitfalls related to deposit refund instruments

6.2.1 *Certifiability*

Pre-conditions for success of this instrument include certifiability that a deposit was paid on the items or actions for which refunds are claimed, and that the items or actions are as claimed. This is a problem, for example, in the recycling of used oil; the returned oil can be contaminated or purchased where deposits were not required. It is a problem with performance requirements for ecosystem restoration; a long monitoring period may be necessary to assess whether performance criteria are met. Such a long time period may be financially or politically unacceptable.

7. Quantity-based instruments involving market creation and trading

Whereas price-based instruments, notably taxes, provide security regarding the cost of a policy objective, quantity based instruments provide more certainty as regards specific policy objectives. These instruments rely upon the incentives of agents to trade responsibilities amongst one another. The classic cases are tradable permits for pollutants, such as sulphur dioxide and carbon dioxide, and tradable fishing quotas. The trades may be based on allowances, such as permitted emissions or fish catch, or on reductions, such as emissions reduction credits or reductions in fishing effort. Typically, agents are assigned some initial responsibility, e.g., allowable emissions, or required reductions, and if some agents are more successful than others in meeting those responsibilities they can trade responsibilities. Although there have been some voluntary cap and trade schemes, most such schemes depend on well-defined, enforceable legal and regulatory frameworks

7.1 Opportunities related to Trading

Tradable fishing rights have been used by a number of developed countries to manage fish stocks. Although resource management underlies their introduction, regulating fishing contributes directly to the wider health of marine ecosystems (McIntyre *et al.* 2007). Setting the allowable catch and then dividing up the rights can be difficult, requiring scientific, economic, and community knowledge. Enforcement can also be a problem, but can range from formal to community actions. Using trading instruments for more complicated conservation objectives may be problematic. Biodiversity conservation is complicated by the fact that there is a multitude of species and interactions that must be preserved. Trading based upon species, per se, or even "bundles" of species would not be a very effective or practical means of protecting biodiversity. Rather, trading of habitats, perhaps weighted for species potential or richness, may be a more useful application of trading. Australia is proposing a program creating tradable rights for landowners who conserve biodiversity on their land; and developers must obtain such rights from a common pool in order to develop land (Jenkins *et al.* 2004). Perhaps the most developed program for biodiversity mitigation is the US wetland banking program introduced under the Clean Water Act of 1972, where wetlands qualities can be used as weights (e.g., Habitat Units) for measuring credits. Both schemes are based on the notion of 'no net loss' of biodiversity. Some researchers have proposed tradable invasive species permits to protect biodiversity (Horan and Lupi 2005).

Another useful example is the recently developed scheme for protecting marine resources in a heavily trawl-damaged area off the coast of California (New York Times 2006). In order to reduce trawl fishing, several non-profit environmental groups have begun purchasing fishing permits from fishermen along the central California coast. The purchases, at a cost of several hundred thousand each, include both the permits and the boats. The environmental organizations then own the boats and permits, and can lease these to fishermen with restrictions on fishing locations and techniques. This would not have been a useful tool if the fishermen would have changed their locations and techniques favourably without the buy-out; but this did not seem to be the case.

In response to regulatory requirements for compensatory mitigation, conservation banks have been established to generate credits for habitat restoration. Conservation banks have been established to mitigate damage to a wide variety of ecosystems, including short-grass prairie and old-growth pine forests in the United States. The most well-known example of conservation banking is the U.S. wetlands banking programs that allow agents to bank and buy wetlands restoration and development credits. There are over 500 wetland mitigation banks operating. When mitigation ratios are set above 1:1, there can presumably be a net gain in wetlands. However, the extent to which banked wetlands represent the same functionality as developed wetlands, and the extent to which the banked wetlands are successful over the long term, limit the possible net gains (Salzman and Ruhl 2001).

Australia has used a trade mechanism to achieve cost-effective salt load reductions in the Hunter River (http://www.ecosystemservicesproject.org/html/publications/docs/Intro_to_MBIs_2005.pdf). Individual polluters are given initial licenses to discharge a given quantity of salt into the river. Polluters can then trade amongst themselves.

7.2 Pitfalls related to Market Creation and Trading

7.2.1 *Assignment and rights, and equity implications*

There must always be an initial assignment of rights. These will often be politically contentious. "Grandfathering" and auctioning are two possible assignment procedures for cap and trade schemes, each with their economic and equity implications. When the value of the permits is high, the initial assignment has significant financial equity implications, and also affects the trading itself. An agent with an initially large assignment has a significant asset, and may use that asset in undesirable ways. For example, if a few agents receive a large number of land development rights, they may be able to control development to their advantage simply by the possession of these rights; they may use them to drive

competitors out of business. In the Netherlands, large companies buy up fishing quotas and lease them to small operators, who receive little profits from their catch (www.colby.edu/personal/t/thtieten/fish-nz.html).

7.2.2 *Measurability and verifiability*

Pre-conditions for successful trading schemes include measurability and verifiability of trades. Tradable permits for pollutants meet these requirements, particularly in those countries that have well-developed permitting and measurement systems. But it is always possible for an agent to cheat by claiming fewer pollutants or greater reductions than is the case; or falsely claiming to have purchased more allowances or reduction credits than is the case. It is not inexpensive to measure and monitor trading schemes.

7.2.3 *Well-functioning trading market*

Another pre-condition for a successful trading scheme is that the trading market be well-functioning, meaning that trades are made when there are mutually beneficial circumstances for the traders. Small trading markets can be monopolized, defeating the presumed benefits of trading. Also, information must be available on what is for sale and who wants to buy. If there are willing buyers and sellers but they cannot find one another easily, the market will function at less than its potential.

7.2.4 *High transaction costs*

Trading involves transactions costs, such as finding sellers and buyers, and establishing the terms of trade. This may be a problem in the case of the CDM of the Kyoto Protocol where potential reforestation and afforestation projects involve many small landholders. Transaction costs can be so high as to prevent the project from going ahead, creating a barrier to small-holders entering the market and trading their carbon credits.

7.2.5 *Cultural pitfalls and strategic bargaining*

Trading schemes may not work in cultures that cannot understand the concepts of trading in such unfamiliar items as rights and actions. And they may not be successful in circumstance where agents are reluctant to give up presumed rights. This has been a problem in establishing water use rights trading in the Western US. While there is a huge difference between the low economic value of water use in agriculture and the high value of water in urban areas, farmers have been reluctant to give up water rights as that may forever alter their ability to farm. While there may be a high enough price at which a farmer will sell, this high price may foreclose any trades of water from low to high value uses. Strategic bargaining between trading parties may lengthen the trading process and even result in the foreclosure of what otherwise could have been mutually advantageous trades. A farmer may begin the bargaining by stating such a high price that buyers presume no reasonable deal can be made, or buyers set initially low prices that sellers walk away; this is a noted issue in residential house sales. The attempts to institute tradable quotas in New Zealand fisheries in the early 1980s were not accepted by the Maori people since it did not coincide with their view of common property resources.

7.2.6 *"Hot spot" problem*

Trading schemes must be set up to avoid adverse environmental consequences. Typically, trading results in shifting activities spatially. There are problems with trading schemes that result in too much of an adverse activity or too little of an activity in one location. An example of this problem can be found in the context of wetland mitigation banking (Salzman and Ruhl 2006). Although there may be no net loss in wetland area, wetlands near urban areas, where the hydrological services are most valuable, are increasingly being destroyed while, in exchange, wetlands are restored in rural areas. This problem can be remedied by restricting trades between donor and recipient regions. But this adds one more layer of administrative complication, which raises the costs. If the hot spot problem is too severe, trading may not be a good idea

7.2.7 *Assuring improvements in environmental objectives*

If desirable environmental behaviours would have taken place in absence of the trading, this market instrument adds nothing to meaningful policy tools. For example, in the case of carbon trading, if an agent receives reduction credits for actions that would be taken anyway, such as reduced timbering, reforestation or emissions reductions, the tradable permit just gives the agent added wealth. However, determining whether an action would have been taken in the absence of the permits is difficult. This risk may be small relative to what can be gained more broadly from the use of tradable permits. There will likely be errors in administration, but these may be acceptable relative to the potential gains from institutionalizing and obtaining acceptance of trading.

8. Demand enhancement

Providing a market environment in which appropriate behaviour enhances the market demand for an agent's products or services creates a reward for that behaviour. Green goods, such as organically grown coffee, are examples. These goods may be formally or informally certified, even receiving "seals of approval." Agents may create their own advertising

around the good characteristics of their products, production processes or agent behaviour unrelated to the product. This may enhance the products' distinctiveness, resulting in larger sales or price premiums. While these demand-enhancing, market-based programs may be useful in achieving environmental objectives they have well-known pitfalls.

8.1 Opportunities related to demand enhancement

A potentially useful opportunity ties agent conservation activities and land practices to the agent's products. Timbering and farming practices could be certified as conservation "friendly" and, as in the case of organically grown products, may bear a premium in the market. Banrock Station winery in Australia markets its participation in the management of Banrock Station wetlands and its contributions to wetland conservation. Shade-grown coffee, which aims to protect forest canopies for wildlife, is another well-known example of tying a private good to a public environmental good. Another example is the certification program of the Forest Stewardship Council that certifies individuals or corporations as practicing good forest management (http://www.fsc.org). Although most certification programs focus on habitat protection, there are a few associated with the harvesting of individual animals or plants, such as the Marine Aquarium Council's program to certify fish harvesting practices in the international aquarium trade.

8.2 Pitfalls related to demand enhancement

8.2.1 *Value added*

A major pitfall is whether there would be enough demand enhancement to merit the agent's effort. Some products or services receive no value-added from being characterized as "green". In other cases, consumers may be willing to pay more for a green product, but not enough to cover the increased costs associated with producing the environmentally-friendly commodity.

8.2.2 *Certification and monitoring*

A second pitfall is the certification process and subsequent monitoring. If certification has no basis in fact, false claims by agents will make consumers leery of certification. There may also be confusion about whether a product is really good for the environment, particularly when the product has both pluses and minuses. Once certification is obtained, agents may alter their products in ways that make them less green; so regular monitoring and recertification is necessary.

Maintaining the distinction of the product may be difficult when there are not separate market distribution networks that keep the friendly products distinct from others. This may be increasingly true as globalization of product markets erases the distinctiveness and origin of products.

8.2.3 *Competition in industry*

While certification can be useful in enhancing product demand, it also has the potential to be used to restrict entry into an industry. For example, while organic products may distinguish sellers, organic certification processes may be so tailored and complicated by existing organic farmers that they create barriers to entry into the industry.

8.2.4 *Sharing the benefits*

Price premiums associated with biodiversity friendly products need to be channelled back to producers. Evidence suggests that with some products it is traders and middlemen who gain disproportionately (Bacon 2005).

8.2.5 *Disadvantaging poor producers*

There is some reluctance and scepticism surrounding motives for introducing eco-labelling and certification schemes given that they inadvertently discriminate against producers who meet the criteria but are not participating in a scheme.

8.2.5 *Label Fatigue*

From the perspective of the consumer, a proliferation of certification schemes

CONCLUSION

Conservation activities are always fraught with issues of costs, benefits, disproportionate impacts, monitoring and enforcement. Market-based instruments can be useful if they help achieve conservation objectives at lower costs, with higher benefits, without undue adverse impacts on selected persons, and with more manageable monitoring and enforcement. Market-based instruments that place prices on ecological services, land uses or other activities establish obligations to pay for what is lost, or receive payment for what is gained. Clear pricing signals make economic calculations regarding conservation activities relatively straightforward, and can be fine tuned to establish many conservation objectives. These instruments can either be punitive, as taxes or fees, or rewarding, such as subsidies and payments. Trading instruments allow for the transferof responsibilities to agents most able to gain, such as those who can achieve conservation objectives most cost-effectively. These instruments can facilitate achieving conservation goals most cheaply and, consequently, may allow for the establishment of even higher objectives.

Demand-based instruments may be somewhat less clear cut than the pricing and trading instruments, since it is not clear how the market demand for an agent's products will be enhanced through the conservation activities. Financial instruments, such as deposit-refund programs or performance bonds, can establish clear, long-term signals regarding whether conservation objectives have actually been achieved.

ACKNOWLEDGEMENTS

The initiation of this work came out of the Valuing Wild Nature workshop (University of East Anglia March 12-16, 2006) sponsored by the Royal Society for the Protection of Birds, Natural England, the UK Government's Department for Environment, Food and Rural Affairs and the Centre for Economic and Social Change in the Global Environment, University of East Anglia.

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AGRICULTURE AND CONSERVATION

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Presentations

Rhys Green of RSPB and the University of Cambridge, UK, discussed reconciling crop production with biodiversity conservation. Agriculture is one of the biggest threats to biodiversity because it leads to extensive loss of habitat and the pesticide usage leads to environmental degradation. Agricultural environmentalists attempt to reconcile the two through two main practices – Land Sparing and Wildlife Friendly Farming.

Land Sparing concentrates on high intensity inputs and productivity on a portion of the land, leaving the remaining land free for biodiversity conservation. Land sparing, if followed properly, would have been successful in its objective. In practice, however, often when land is left uncultivated for biodiversity conservation, it is used for non-conservation processes like building roads and houses. This severely affects the feasibility of this form of biodiversity conservation.

Wildlife Friendly Farming is low in production and yield, but beneficial for the wildlife in the area. However, Wildlife Friendly Farming does not leave much land empty for pure biodiversity conservation. Both methods are likely to lower financial profits and farmers are compensated for economic losses that they suffer in order to help species survive. The viability of these methods also depends on the ecosystem of the area. Studies must be conducted before a method is chosen. With global food demands growing by two to three times by 2050 it is essential that we find methods of farming that can cater to the growing needs of the world as well as help conserve biodiversity.

Vijay Jardhari of the *Beej Bachao Andolan* (BBA, or Save the Seeds Movement), presented his experiences with conserving agro-biodiversity (agricultural biodiversity), in his village Jardhar in Uttarakhand, India, and in other parts of the region through the BBA. He tracked the changes in perceptions and methods of farming. Traditionally, farming was an esteemed profession and soil was a precious resource that had to be valued. It was treated like a living entity that needed nurturing and nourishment. Organic methods of farming were used that naturally let crop biodiversity flourish and kept the soil healthy.

Around 40 years ago, the Indian government propagated the use of high yielding varieties (HYV) of crops by doling them out at subsidised rates. These varieties needed chemical fertilizers and slowly changed the entire system of farming that originally existed. Initially people were surprised by the substantial increase in productivity, but over a period of time they realised that the yield stagnated or reduced with every year while the need for expensive and harmful chemical fertilizers and pesticides increased. The people of Jardhar decided to revert back to their traditional practices of farming. The main method they used was the *Baranaja* system where a variety of crops and plants are grown together in what seems to be an incoherent and random melee, but the system is a time-tested method of growing a variety of crops, providing a variety of needs, as also allowing biodiversity to flourish and keeping the soil healthy and productive.

The *Beej Bachao Andolan* (Save the Seeds Movement) was later started in the village to work towards recovering seeds that were lost due to the heavy influx of HYV (high-yielding variety) seeds during the Green Revolution. Since the starting of the *Beej Bachao Andolan*, hundreds of varieties of seeds have been recovered. There are a number of *Mahila Mandals* (women groups) that look into farming and biodiversity issues.

While protecting agro-biodiversity, the village simultaneously put systems in place to protect its forests. This has resulted in healthy forests and land, an increase in biodiversity and high underground water tables. This is essential for places like Jardhar where a vast majority of the population is still directly dependent on agriculture and forest produce. The *Beej Bachao Andolan* also focuses on information dissemination on conservation.

The major problems faced by Jardhar are the waning interest of the younger generation in the movement and the threats from destructive development projects like mining. Currently, the village is also trying to stop hybrids and genetically modified (GM) crops from entering their farming systems. They are fearful that the government will propagate GM seeds by selling them at subsidised rates and advertising them as the strongest and highest yielding varieties of seeds,

A report on the session held at the International Conference on 'Conserving Nature in a Globalizing India' at Bengaluru; February 17-19, 2009

much like they did with HYV seeds. The people of Jardhar think that since Uttarakhand is supposed to be an organic state, GM seeds should not be propagated.

Siddappa Setty of the Bangalore-based NGO Ashoka Trust for Research in Ecology and Environment (ATREE), talked about the agricultural and wildlife conservation practices of the Soligas, a tribe in the Biligiri Rangaswamy Temple Wildlife Sanctuary (BRTWLS). The Soligas farm on land and collect non-timber forest produce (NTFP) from within and outside the sanctuary. Prior to 1972 (the year the Wildlife Act was promulgated), wild animals consumed half of the crops that were cultivated by the tribe, which they tolerated, but later as their access to land reduced dramatically due to conservation policies, they could not afford to lose such vast quantities of crops anymore.

Traditional methods of farming are still used to grow a variety of crops and conserve seeds. They previously used shifting cultivation, leaving land fallow for four to five years to let it regenerate before using it again. This method was later prohibited within the BRTWLS, and broadcast sowing methods in settled agriculture were adopted. However, the irregular crop arrangement makes it difficult to remove weeds. To tackle this problem, the sowing patterns were changed from broadcast to in-line. The systematic rows of crop made it easier to locate and remove weeds. However, different problems cropped up with this method and it was discontinued. Farmers on hill slopes and those who did not have cattle to help them cultivate, found this method cumbersome and were the first people to revert to their earlier methods. Farmers also realised that removing the weeds gave wild boars better access to the crops. After four years of experimenting, most of the farmers have returned to broadcast farming. Traditional farming is currently threatened both by the increase in the number of coffee plantations in the area as well as the excessive growth of Lantana in the WLS, which in turn is forcing wild animals to enter the Soliga farms in search of food.

Raman Sukumar of CES and IISc, spoke about human-elephant conflict in agricultural landscapes. According to Sukumar, this is an age-old problem and cannot be completely eradicated, however, one can definitely work towards reducing losses. There should be extensive studies on the extent of damage caused by elephants along with the variety and quantity of food available in the forest, as this information will help unravel the motivational factors behind the instances of crop raiding. After all, elephants take to fields for the same reasons that humans do – limited access to forest produce, and for the nutrition and the taste of farm grown crops.

These studies can be followed by bringing about changes in cropping patterns and enforcing landscape planning to increase the availability of nutritious food for the elephant populations within forests. However, increasing forest cover does not necessarily reduce human-elephant conflict because degraded land often has a higher carrying capacity of elephants than a rich forest. Often more elephants are found in buffer zones than in core areas. This is apparent in Joint Forest Management sites where forests have provided shelter but not food for elephants. Thus, they raid crop from farms nearby and then use the newly regenerated forests to hide. Sukumar also noted that elephants are now travelling to forests where they were not found earlier. He said that although the number of conflicts has reduced over the last 20 years because the male population has decreased, the compassion people had for the animal has also decreased. Thus, communities that traditionally refused to kill elephants even when there were human casualties, are now open to culling animals to prevent farm raids.

Discussion

The presentations were followed by a discussion. One of the main questions revolved around what individuals could do to support these efforts. Jardhari asked people to revaluate their own lifestyles and find out where they could make changes. He suggested small things like terrace gardens, buying locally grown food and organic food if it was possible. He also asked people to reconsider eating industrial meat because the production and transportation of such meat costs a lot in terms of resource consumption.

Some participants questioned the viability of organic farming by stating that it was replaced by Green Revolution in the 1970s because organic farming was incapable of producing sufficient quantities to feed the country. They pointed out that food needs are much higher than they were before and will double or triple in the next few decades and wondered how organic farming would be sustainable now if it wasn't earlier. They asked if perhaps, it was necessary to continue with non-organic methods of farming and add to them by using genetically modified (GM) seeds.

The speakers reminded the audience that the Green Revolution was aggressively pushed onto farmers by heavily subsidising the cost of HYV seeds and fertilisers. However, these prices changed, the quality of the soil decreased and ultimately the production levels dropped, making this form of farming unsustainable. Furthermore, it has led to farmer suicides across the country and these deaths must be accounted for while assessing the sustainability of non-organic methods of farming.

The speakers acknowledged that organic farming also had its drawbacks and said it should be used only when it seemed to be the most sustainable (in terms of economics

and ecology) option. Unfortunately, several farmers have forgotten traditional methods of farming because they have been using the Green Revolution methods for decades. This meant that even though farmers might want to revert back to organic farming they no longer have the means and knowledge to do so.

The speakers feared that pushing GM seeds would have effects similar to that of the Green Revolution. The solution to this was forming networks that could help each other with farming methods and seeds. Linking markets and locally produced food was also the need of the hour. This has been achieved by the Deccan Development Society in Zaheerabad (Andhra Pradesh, India), by linking the public distribution system to a variety of local, organically produced, nutritious crops.

In response to the question about the looming food crisis, the speakers said the solution was not more intensive farming on larger patches of land but farming more essential foodstuffs rather than non-essential cash crops. They also recommended adopting eating habits that are easier to sustain like eating more bajra and unpolished rice. Finally, one would also have to question the social hierarchy of farming methods. For instance, dry land farming is viewed as inferior to water intensive irrigated methods even if it is more effective under certain conditions. If such false hierarchies were done away with, appropriate methods would be adopted to suit particular land types and farming would be more effective. Working on these structures takes time and energy. In Zaheerabad, it took fifteen years to prove that dry land farming was the more effective method.

The session ended with a discussion on GM seeds. A comparison was drawn between growing monocultures of GM seeds and using traditional organic forms of agro-biodiversity. People argued that if a farm has a rich diversity of crops, this diversity acts as a buffer. If a particular crop gets infected and dies, there will still be other crops that assure the farmer of some food and sustenance. This was not the case with monocultures of hybrid, HYV, or GM crops as the produce of a whole farm would be wiped out if an infection or a disease attacked the crop. The discussion veered to the ethical arguments for and against GM, and naturally available seeds. People were divided on whether they were more comfortable with one or the other kind of seeds. Participants agreed that there was insufficient scientific data to prove whether one form of farming was better than the other due to a paucity of examples of direct comparisons between the two forms. However, observations from the various examples of organic, sustainable, biodiverse farming suggested that such alternatives could be viable in the long run for India, and provide appropriate resolutions for the conflicts between agriculture and biodiversity conservation.

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COMMUNITY-BASED CONSERVATION

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Ashish Kothari of Kalpavriksh, Pune, gave an overview of community-based conservation in India. He specified three areas that needed to be focused on, namely community conserved areas (CCAs), protected areas (PAs) and landscapes outside CCAs and PAs.

CCAs can be roughly defined as natural and modified ecosystems that contain significant biodiversity values, ecological services and cultural values that are voluntarily conserved by indigenous/mobile/local communities through customary laws or other effective means. In most cases these areas have been beneficial for the local ecosystem, the biodiversity, the people and the adjoining areas.

Internationally, several policies have been formed to acknowledge CCAs, like the Convention on Biological Diversity, which has been ratified by India. There are also several Indian laws and policies that could back CCAs or co-managed (CM) areas. The National Wildlife Action Plan talks about CCAs and CMs; Wildlife Protection Act (amended in 2002) brought in concepts like Community Reserves and Conservation Reserves; The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006, mentions community forests; the Indian Forests Act, 1927, mentions village forests. However, challenges still exist in the form of appropriate implementation of these laws and policies. Furthermore, destructive development projects and globalisation have led to the watering down of these laws and policies.

While acknowledging the importance of PAs to protect certain species and ecosystems, one must realise that over 3 million people live inside them and the creation of such PAs has led to the displacement and disempowerment of these individuals. This has caused several problems like loss of traditional forms of conservation, clashes with the forest department, illegal poaching and timber extraction, to name a few. This often negatively affects conservation itself, and defeats the purpose for which PAs were created, apart from creating enormous human suffering. But there are some initial changes taking place, such as Periyar Tiger Reserve where officials were working with local adivasi communities to enhance their livelihoods and involve them in protection. In this case too, developments in international policies such as the CBD Programme of Work on Protected Areas, which emphasised collaborative management and the integration of conservation with livelihoods, could lead to more equitable conservation within India.

The landscape approach seeks to connect different areas under conservation and sustainable use, and form extensive stretches of conserved areas rather than little islands of protection. This could include CCAs, PAs and many other forms of conservation sites to form a strong mosaic of conservation.

The overview emphasised the need for participatory methods of conservation that ensured wildlife protection and the rights of local people to life and livelihood.

Kanhaiya Gujjar, a villager from Bhaonta-Kolyala villages working with the NGO Tarun Bharat Sangh in Rajasthan, spoke on community-based landscape conservation in Rajasthan with reference to the River Arvari in Alwar district in Rajasthan. The area had thick forests, but lost them during colonial rule. This trend continued after India became an independent nation and caused many problems like the drying up of the Arvari, severe droughts during dry seasons and excessive soil erosion during the monsoons. In 1987, along with the Tarun Bharat Sangh (TBS), the villagers conducted a meeting to address various local problems. They decided to regenerate their forest and revert to traditional forms of water management to restore the ecological balance of the area. To achieve this, rules about forest use were implemented and traditional water harvesting structures (*johads*) were constructed. Their efforts paid off when the river regenerated and started flowing again. Currently, there are 30 tanks in the area as opposed to the 4 that existed when the movement started.

Several threats have cropped up since the revival of the river. One of the main problems was the fishing contracts leased out by the government to private bodies. The TBS opposed this and won the struggle. They realised the need for their own governing body that would protect the river from such instances in the future. They formed the Arvari Sansad (Parliament). This is the first peoples' parliament in the country. It has 242 elected members and various internal communities that look into matters related to the river (including water sharing, wildlife and forest conservation, inter-village disputes, and others). However, they still face

A report on the session held at the International Conference on 'Conserving Nature in a Globalizing India' at Bengaluru; February 17-19, 2009

various challenges including boundary issues with their neighbours, threats of mining and other development projects, election politics that threatens to fragment their society and insufficient cooperation from government bodies.

Tsilie Sakhrie, an Angami tribal from the Khonoma Tragopan Sanctuary Trust in Nagaland, spoke about community conservation of the Blyth's Tragopan. Khonoma is a village in Kohima district, Nagaland, that is rich in biodiversity and home to the threatened Blyth's Tragopan. Sakhrie and a few others set out to protect this bird and conducted various conservation activities. Since, hunting was traditionally acceptable and glorified in Khonoma, they initially faced a lot of resistance and opposition to their conservation efforts. Through continuous interactions with the community, Sakhrie and his colleagues made people realise the importance of conserving the Blyth's Tragopan and the village moved away from hunting and towards conservation. In 1998, the Khonoma Nature Conservation and Tragopan Sanctuary was officially established. It is managed and supported by the local community.

Vijay Jardhari, a farmer, spoke about community conservation in his village Jardhargaon in Uttarakhand. This village is situated in the Himalayan foothills at an altitude of 1,500 metres. It has 17 settlements with 8-10 families each. The major occupations here are agriculture and animal husbandry. They rely on local forests for firewood, fruits, fuel and medicinal plants. By 1980, deforestation activities conducted by the forest department and local people had left the forests almost bare. Jardhari was a part of the Chipko movement and was aware of the power of peoples' movements. In 1980, the people of Jardhar had a meeting and decided to work towards regenerating their forests. They formulated rules and appointed guards to protect the forests. They formed a *Van Suraksha Samiti* (VSS) or Forest Protection Committee, and appointed a forest guard with their own resources. Within three years, the forest had regenerated substantially; within 30 years it had become dense with high biodiversity.

Having dealt with their forests the villagers also decided to stabilise their farming methods. Chemical fertilisers had affected farming in the area so they reverted to traditional forms of farming. They collected and distributed local seeds and started the *Beej Bachao Andolan* (Save the Seeds Movement). Despite their success they face several problems. There has been a significant increase in human-wildlife conflicts, the community natural resource management enjoys no legal backing, and government policies that promote chemical intensive farming methods are in direct conflict with their traditional methods of farming.

Anil Bhardwaj of Wildlife Institute of India, Dehradun, talked about the ecodevelopment project in Periyar as an example of successful local community involvement in a tiger reserve. In the 1980s and 1990s, Periyar was viewed as a rich forest, but was actually riddled with problems ranging from ganja cultivation and poaching to waste problems caused by tourists and pilgrims. The roots of these problems lay in poor park management and heavy dependence of local people on the forest. Thus, it was decided to pilot an eco-development project to meet the needs of conservation and livelihood. Local people would be involved in protecting the PA and alternate forms of livelihood would be made available for them to offset the losses accrued by changing their traditional methods of using the forests. The project also envisioned converting poachers into protectors, forming women groups and local self-help groups to create a strong base of local people who would support the project with their knowledge of the forest and learn new skills to propel the project further. They worked towards creating several eco-development committees that handled different issues, helped local people get rid of their debts and arranged for them to be involved in conservation and documentation work. Local communities are trained to conduct eco-awareness camps and are part of regularising the pilgrims in the park. Through a slow process that began with creating a relationship based on trust between the local people and forest officials, a working model of joint conservation has been created.

Charudutt Mishra of Nature Conservation Foundation and the Snow Leopard Trust spoke on community-based management of human-wildlife conflict, with special reference to the work going on in Spiti, Ladakh. He spoke about two basic dimensions of the effort – understanding the conflict in the area, and managing it. While undertaking the first part, one must take stock of the situation and understand the perceptions and psyche of the people in the area apart from the actual information on losses. These are extremely important when it comes to actually implementing the management plans. In Spiti, Snow Leopards were highly dependent on livestock in some areas and were responsible for *c.* 12% of the livestock losses. The perceptions of the damage caused by the animal were magnified because of a lack of data (actual losses, causes, circumstances of loss) and because of insufficient and delayed compensation for livestock losses. The best way to deal with human-wildlife conflict, was to address all three of these simultaneously – reducing livestock losses, economic offsetting and increasing the social understanding of the situation. In Spiti, they reduced livestock losses by putting better herding methods in place, and increasing the populations of wild prey of the Snow Leopard. They created community-based insurance which is run by the community and gives complete compensation much faster than the government bodies because of simpler

verification and disbursal procedures (uncovering false claims is easy in a small community). Conducting educational programmes and giving incentives to undertake conservation have increased social understanding. This programme has been running successfully for over five years and livestock losses have reduced dramatically. Mishra pointed out that while it was important to have community-based management plans, there should also be governmental support.

Panel discussion

Madhu Ramnath, an ethnobotanist, talked about the importance of lesser known non-timber forest produce (NTFP). He said that while the most prominently discussed forms of NTFP tend to be profitable ones like Tendu patta (*Diospyros melanoxylon*), sal seeds (*Shorea robusta*) and Mahua (*Madhuca indica*), there exists a rich diversity of non-commercial NTFP that are vital for the health and subsistence of local communities.

The commercially viable forms are used to make a variety of products from cigarettes to alcohol. The collection processes are often highly politicised, involving power struggles between local communities, forest departments, local governments and private bodies. The other forms of NTFP exist in the form of fibres, leaves, poisons, berries, yams, etc. with specialised functions related to health and survival.

With 20% of our population still directly dependent on such produce, one should not undermine the power of these forms of NTFP. Ramnath stated that although commercial NTFP assured local communities some money, the non-commercial ones were far more important because they could ensure good health, food security and sovereignty. They also required and could ensure the maintenance of healthy, biologically diverse forests.

Sharad Lele from the Institute of Social and Economic Change in Bengaluru, spoke on forest-based enterprise and community-based conservation. He enumerated the barriers that impeded the two from interacting effectively. The attitude of those in power is the biggest barrier that prevents local communities from taking part in conservation activities. He pointed out that in all the case studies discussed in the seminar, local communities had to prove their worth as conservationists to external bodies before they were allowed to partake in the process of conservation. Often, when the local communities are involved in conservation processes, they are given menial tasks or ones with lower levels of responsibility. This is indicative of the level of trust extended by external bodies to the community. The right of local people to be intricately involved with wildlife conservation and eco-tourism in their own area should be acknowledged. Ultimately, instrumental approaches to CBC have been used rather than focusing on rights-based approaches. Another problem was the paucity of formal spaces where local communities could legally partake in conservation efforts. This could change with the implementation of the Forests Rights Act because it has potential to acknowledge these rights. Lele also reminded external bodies that it is alright if the fiscal profits expected by local communities from eco-tourism and other profit generating enterprises are lower than what the external bodies expect.

Tushar Dash from Vasundhara in Orissa, spoke about community conservation and the Forest Rights Act. Orissa is a state with 62 tribes where 13 primitive tribal groups are mostly forest dwellers, 44% of the land is scheduled area and over 40% of the people are critically poor and dependent on the forest for livelihood. Thus, it is important to recognise the rights of local people, whose lives have been and continue to be, intricately linked with the forest, while looking into conservation issues. He talked about two forms of conservation: the exclusive approach and the community conservation initiatives (CCI) approach. The former works towards creating conservation enclaves and normally ignores or denies traditional practices, the rights of local people to be involved in conservation processes and their rights to livelihood. The latter is normally based on traditional knowledge and practices that have developed over time and addresses the issues of rights and livelihoods. Traditional forms of CCIs are present all over Orissa. Currently, there are about 12,000 forest protection groups working around two million hectares of forest rich in biodiversity. This includes initiatives in wetlands and coastal areas, and species protection and conservation based on cultural or spiritual beliefs.

These initiatives require legal backing, recognition of rights and protection from development threats. The Forest Rights Act (FRA) has, to some extent, achieved these goals. It has been used in places like Nayagarh where 200 villages have claimed rights over community forests that they have been protecting. In Niyamgiri, the Dongria Kondhs have used FRA to fight a mining project that threatens the area. Section 5 of the Act gives *Gram Sabhas* the right to form conservation and development committees, and Community Biodiversity Management Plans have also been used to increase local participation in conservation processes. Thus, the FRA has the potential to ensure greater involvement of local people in conservation efforts. But the main challenge lies in making more people aware of the act and in implementing it.

Nitin Rai of Ashoka Trust for Research in Ecology and Environment (ATREE), Bengaluru, talked about community conservation in Biligiri Rangaswamy Temple Wildlife Sanctuary of Karnataka. There exist, within the sanctuary, several sacred sites of a tribe called the Soligas.

Most of these sites have not been identified on modern maps. There are five tribes with a total population of 12,000 who live in and around the sanctuary. They have created a cultural map, where 593 sacred spots have been denoted. The Soligas also defined various vegetative classes that were highly specialised, based on information like the contour of slopes, the composition of the area, the density of flora and several other similar pieces of information. This map, with its different vegetative classifications and cultural sites, is a historical and cultural map of the Soligas. They see it as a method of supporting their right to claiming the forest and argue that they can claim the land because they have used the same method employed by urban people to claim land – which is, naming and mapping areas. There are various efforts towards claiming these rights through Section 33b of the Wild Life Protection Act (2003 amendment) and Section 5 of the Forest Rights Act.

General discussion

After the presentations and panel discussion, there was a question-answer session and a discussion. The discussion revolved around the problems of CBC. This included the fallouts, loopholes and unforeseen complications of this method of conservation.

One common problem in most of the successful sites was an increase in human-wildlife conflicts, especially with monkeys, wild boar and nilgai. The discussion brought out a variety of possible solutions ranging from culling and hunting to changing cropping patterns. However, the group acknowledged the difficulties in implementing these methods due to religious/cultural values attributed to the animal in question and due to ethical doubts about the right to cull animals. Other solutions were urgently needed.

Conflicts between generations based on changing values and materialistic desires are also common to these communities. Younger generations often do not wish to actively continue with the traditional paths that the previous generations have created. This problem becomes acute when destructive development projects, that claim to offer employment and salaries, are proposed in these areas. While the youth focus on the money that could be earned through these projects, the older generations focus on the changes in the ecological conditions of the area and social fabric of the community. Kanhaya Gujjar shared his experiences with the group where families did not speak to each other because they differed over a mining project that was coming up in their area. However, when the youth saw the rapid changes in the society that took place because of the influx of foreigners, they realised that the social cost outweighed the monetary benefits and they too fought against the mining project.

Some people wanted more scientific data to prove the effectiveness of CBC. A need for scientists and researchers to conduct studies on the feasibility of these initiatives was identified. These studies could determine factors that have helped or impeded the CBC site and subsequently help with future endeavours.

Part of the discussion revolved around what urban people could do to contribute to CBC initiatives. One method was supporting similar activities in their own areas. An appeal was made to support laws and policies that helped CBC. The FRA was taken as an example of a law that could give people the rights they have long been denied. However, there has been misguided opposition to this act, and lawsuits aimed at nullifying the act because it is viewed as a threat to conservation. Rather than removing the act, people could work towards improving it through amendments and through its implementation, and ensuring that it aids conservation processes.

An important point from the talks that was repeated in the discussion was that the CBC may not work for all ecosystems and people. It is not a panacea for all situations, but one in a larger mosaic of conservation methods.

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ESTIMATION OF STRIPED HYENA *HYAENA HYAENA* POPULATION USING CAMERA TRAPS IN SARISKA TIGER RESERVE, RAJASTHAN, INDIA

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We used camera trap based capture-recapture method to estimate the population size of Striped Hyena *Hyaena hyaena* in Sariska Tiger Reserve. Twenty-five days of camera trapping was done with a sampling effort of 1,675 trap nights from January to April 2008. Camera traps yielded a total of 85 Hyena photographs of 26 individuals within an effective trapping area of 229.7 sq. km. Heterogeneous Jacknife model was best fit in estimating population with a capture probability of 0.31 P(hat). Population size was 34 ±(SE 5.4) and density was estimated as 15.1 ±6.2 hyena/100 sq. km (spatially explicit model). The study revealed that camera based capture-recapture method is an effective tool for assessing the population size of Striped Hyena in Sariska.

Key words: Camera trapping, *Hyaena hyaena*, individual identification, Sariska Tiger Reserve

INTRODUCTION

The Striped Hyena *Hyaena hyaena* is one of the most important large scavengers; its role in clearing off carrion in tropical ecosystems and in recycling mineral compounds from dead organic matter enhances its biological importance (Kruuk 1976). They generally prefer arid to semi-arid environment and avoid open desert and dense thickets (Prater 1971; Kruuk 1976; Leakey *et al.* 1999). The current distribution range of this species extends from East to North-east Africa, through the Middle East, Caucasus region, Central Asia and into the Indian subcontinent (Mills and Hofer 1998). In the Indian subcontinent, they occur in arid and semi-arid ecosystems, as well as in the extremely wet regions of south-western coast (Prater 1971; Karanth 1986). According to Mills and Hofer (1998), the estimated population of Striped Hyena in India was *c.* 1,000, which was a gross under-estimate. The camera trap based capture-recapture framework to estimate population of large carnivores, based on natural markings on their bodies, has proven to be amongst the most successful non-invasive method for species such as Tiger *Panthera tigris* (Karanth and Nichols 1998; Karanth *et. al.* 2004; Contractor 2008; Sharma *et al.* 2009), Leopard *Panthera pardus* (Chauhan *et al.* 2005; Edgoankar *et al.* 2007; Harihar *et al.* 2009), Jaguar *P. onca* (Silver *et al.* 2004), Geoffrey's Cat *Oncifelas geoffroyi* (Cuéller *et al.* 2006), Snow Leopard *Uncia uncia* (Jackson *et al.* 2006) and Striped Hyena (Singh 2008). This technique takes advantage of distinctive individual markings through photographs for even heavily furred animals such as Ocelot *Leopardus pardalis* (Trolle and Kery 2003), Wolf *Chrysocyon brachyurus* (Trolle *et al.* 2007), and Puma *Puma concolor* (Kelly *et al.* 2008). The individual identification in Spotted Hyena has been done earlier using pelage and nicks in ears (Holekamp and Smale 1990; Hofer and East 1993). The present study was aimed to estimate the population of Striped Hyena on the basis of spatially explicit closed capture models in a semi-arid landscape and to standardize the camera trapping method.

MATERIAL AND METHODS

Study area

The study was conducted in Sariska Tiger Reserve (Sariska TR), (25°5'-27°33' N; 74°17'-76°34' E), which is situated in the Aravalli Hill Range and lies in the semi-arid part of Rajasthan (Rodgers and Panwar 1988). The total area of the Tiger Reserve is 881 sq. km, with 273.8 sq. km as a notified National Park. The vegetation of Sariska corresponds to Tropical dry deciduous and Northern Tropical thorn forests (Champion and Seth 1968). The Park supports various carnivore species such as Tiger, Leopard, Striped Hyena, Caracal *Caracal caracal*, Jackal *Canis aureus*, Jungle Cat *Felis chaus* and prey species like Chital *Axis axis*, Sambar *Rusa unicolor*, Nilgai *Boselaphus tragocamelus*, Common Langur *Semnopithecus entellus*, Wild Pig *Sus scrofa*, Porcupine *Hystrix indica*, Rufous-tailed Hare *Lepus nigricollis ruficaudatus* and Indian Peafowl *Pavo cristatus* (Sankar 1994). There are 32 villages within Sariska TR. A large number of buffaloes, goats, sheep and cattle are kept by people living in villages.

METHODS

A preliminary survey was carried out from November to December 2007 in the intensive study area of 80 sq. km in

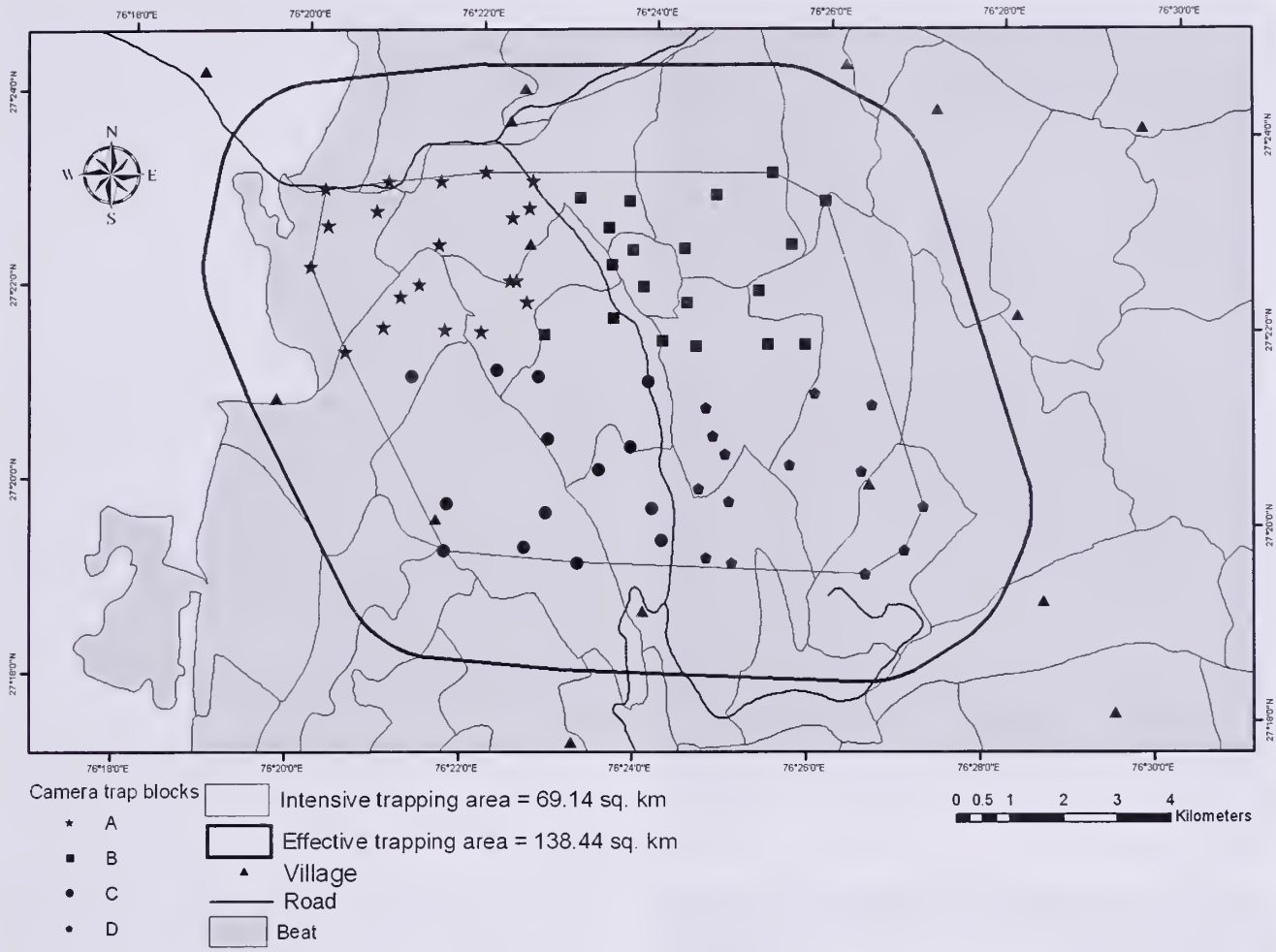

Fig. 1: Camera trap locations in intensive study area of Sariska Tiger Reserve (January to April 2008)

the National Park. Indirect signs such as spoor and scats of Hyena were identified and marked using a handheld Global Positioning System. Striped Hyena camera trapping data was collected from January to April 2008 in the intensive study area. We placed the camera in 1x1 sq. km grid. Camera traps were placed on the basis of hyena evidence (tracks, scats) on the trails. We used 20 units of analog cameras that worked on passive infrared motion/heat sensors. The camera traps were equipped with 35 mm lens which recorded the date and time of each photograph. The camera delay was kept at minimum (15 seconds) and sensor sensitivity was set at high. A total of 67 locations were selected for the placement of camera traps in the study area (Fig. 1). The study area was divided into four blocks of 20 sq. km each. Block A consisted of 20 camera trap sites, block B had 19, C and D blocks had 14 camera trap sites each. The mean inter trap distance was 726 m (ranging from 700 to 1,200 m). Camera traps were operated for 25 consecutive occasions with the total sampling period of 100 days (1,675 trap nights). Individual Hyena obtained from camera trap photographs were identified by a combination of distinguishing characters such as position and shape of stripes on flanks, limbs and forequarter, pattern and spots on flanks (Schaller 1967; Karanth 1995; Singh 2008) (Fig. 2). Any photograph with distorted perspective, or which lacked clarity, was discarded (n=8). Every Hyena captured was given a unique identification code like H1, H2, H3, etc. Capture history of each individual was generated in an X matrix format (Otis *et al.* 1978). Each day-wise sampling occasion was constructed for example by taking 1st day from block A, B, C and D as day one for entire study area and all subsequent days were combined in this manner to construct a matrix of capture for study area (Karanth 1995). Estimation of population size using closed capture models requires the population under investigation to be both demographically and geographically closed. We tested for population closure using software CAPTURE (Otis *et al.* 1978; Rexstad and Burnham 1991). The density (D) of Hyena in the study area was estimated by spatially explicit model (Efford 2004; Sharma *et al.* 2009) using Density 4.1 software (Efford 2004). The density of Striped Hyena was calculated by four different

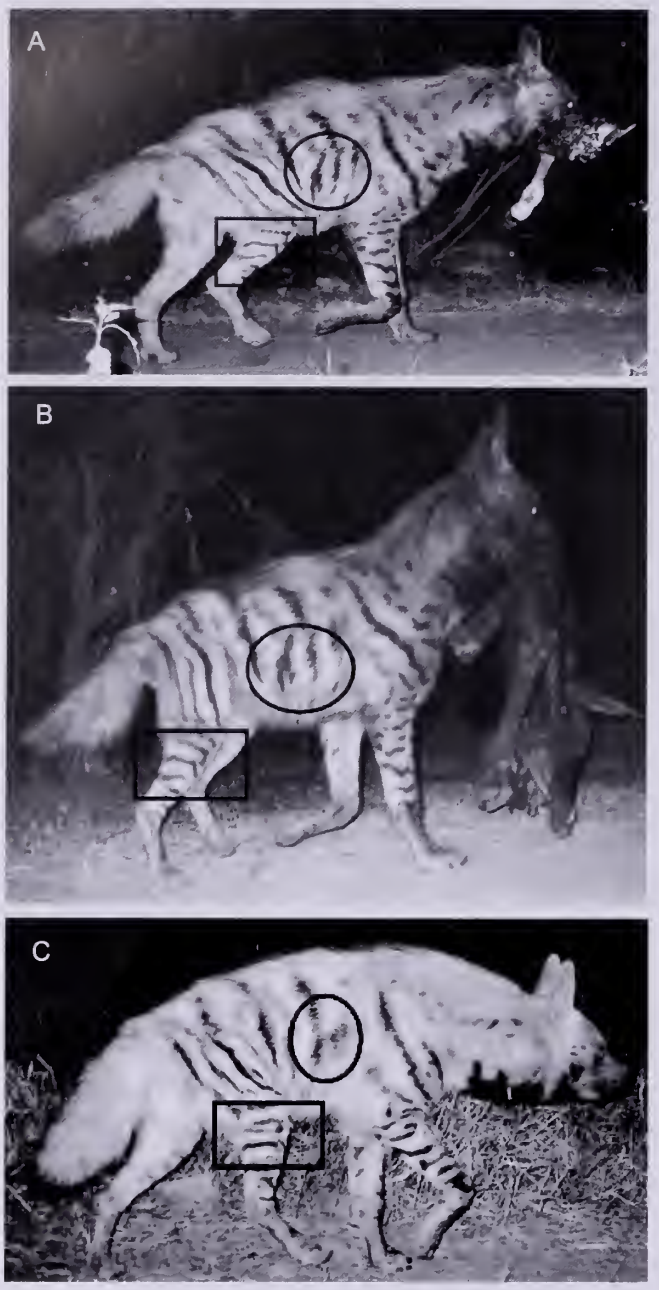

Fig. 2: Two individual hyenas captured by camera trap (A) and (B) show individual H4 with stripes and spots on flanks identical in shape and pattern. While (C) shows a different individual H10 with stripes and spots on flanks being clearly different in shape and pattern

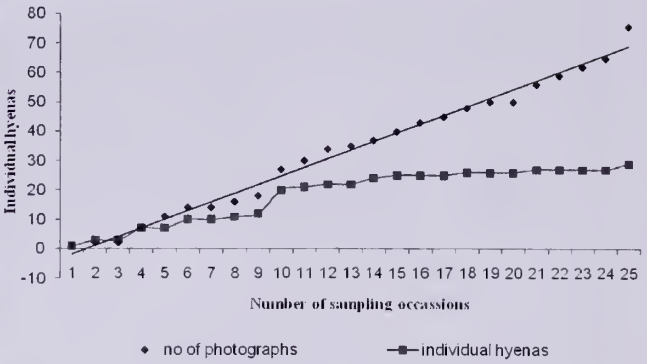

Fig. 3: Number of Striped Hyena photographed and number of hyena photographs with increasing number of sampling occasions to evaluate trap shyness and sampling adequacy in intensive study area

methods such as full mean maximum density moved (MMDM), half MMDM, spatially explicit Inverse Prediction density (IP dens) and spatial Maximum Likehood density (ML dens) (Sharma *et al.* 2009).

RESULTS

The intensive trapping resulted in a total of 85 photographs of 26 individual hyenas, based on right flank profile, as the number of individuals identified from the right flank was maximum. The 67 trapping stations covered an effective trapping area (ETA) of 229.7 sq. km (Full MMDM) and the number of new individuals was found to stabilize after the 19th trap night (Fig. 3). Population was closed for the sample period (z = -0.49, P=0.31) (Otis *et al.* 1978). The overall model selection test based on discriminant functions using the model selection algorithm of CAPTURE identified Mh as the most appropriate model in our study. The model selection scores are as follows: M (h) = 1.00, M (tb) = 0.99, M (o) = 0.96, M (b) = 0.82, M (tbh) = 0.78, M (bh) = 0.68, M (th) = 0.42, and M (t) = 0.00. The estimated Hyena population size (N) was = 34± SE (5.4) (Table 1). Density (D) and flank data using spatial explicit model was 15.1 individual/100 sq. km. MMDM and effective trapping area (ETA) was calculated by different methods using the program DENSITY 4.4 (Table 1). Half normal detection function fitted the best and

Table 1: Density estimates of Sriped Hyena in Sariska Tiger Reserve (January to April 2008)

Model	N	SE(N)	P (hat)	Methods for Calculating ETA	Width (km)	ETA (sq. km)	D (hyenas/ 100 sq. km)	SE
Mh (Jackknife)	34	5.4	0.31	MMDM/2	1.832	138.9	24.5	4.3
				MMDM	3.663	229.7	14.9	3.0
				IP DENS	-	-	15.1	6.2
				ML DENS	-	-	12.7	2.8

(N= Population estimate, P (hat)=capture probability, Width=Buffer strip width, ETA=effectively trapped area, D=Density estimate, MMDM=mean maximum distance moved, IP Dens=Inverse Prediction density, ML Dens= Maximum Likelihood density, SE = Standard error)

the density arrived from right half MMDM densities were 24.5 individual/ 100 sq. km and 14.9 individual/ 100 sq. km respectively. Spatial density and full MMDM yielded almost similar results.

DISCUSSION

The capture-recapture technique based on camera trap photographs of Hyena provided a statistically robust estimate in estimating the population. We had also corroborated hyena tracks and photographs at camera location for trap shyness response and did not observe any behavioural response during the study period. Effort required in terms of sampling occasions suggested that a minimum of 20 days are required to get reliable density estimates for hyena in the study area. Out of 85 captures, 12 individual Hyena were recaptured more than three times, 4 individuals were captured twice and 10 individuals had single captures. Some traps showed very high capture rates (2 to 20 captures/trap location), while individual captures/trap ranged from 1 to 8 individuals/trap location. Camera traps deployed near villages Haripura and Kiraska showed high individual capture rates such as 11% (n=7) and 14% (n=9) respectively. This may be attributed to availability of carcasses (livestock) in and around these villages on which hyenas might be scavenging. The estimated Hyena density in Sariska TR is the highest as compared to available studies in India and Africa (Kruuk 1976; Wagner 2006; Singh 2008; Wagner *et al.* 2008) and this might be attributed to the availability of high wild prey base and domestic livestock, i.e., of 105 animal/sq. km and 222 animals/ sq. km respectively (Avinandan *et al.* 2008; Sankar *et al.* 2009). Spatially explicit models and full MMDM give reliable estimates of density (Sharma *et al.* 2009) and we chose these estimates for density estimation. The camera trap based capture-recapture method is proven to be good to estimate Hyena abundance and can be reliably used in various habitat types.

ACKNOWLEDGEMENTS

We thank Rajasthan Forest Department for facilitation of this work in Sariska, as a part of 'Ecology of Leopard' research project conducted by the Wildlife Institute of India. We thank Director and Dean, WII, for their encouragement and support provided for the study. We also thank anonymous reviewers for their valuable comments on the draft manuscript.

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HUMAN-ELEPHANT CONFLICT IN A COLONISED SITE OF DISPERSED ELEPHANTS: KOUNDINYA WILDLIFE SANCTUARY (ANDHRA PRADESH, INDIA)

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This paper discusses human-elephant conflict (HEC) in Koundinya Wildlife Sanctuary (KWS), one of the two sites in Andhra Pradesh colonized by elephants during the 1980s after dispersing from sites in Tamil Nadu and Karnataka states. The nature and extent of the past and present HEC, causes for the conflict, mitigation measures adopted, and their effectiveness are discussed based on a one year study (January-December 2005). The findings reveal that the primary reason for the decline in HEC is due to the decline in elephant numbers, especially adult bulls in the case of man slaughter, and that the crop damage mitigation measures adopted by the Forest Department have not been a success on the whole. As for tackling HEC, we suggest translocation of the animals to other elephant habitats as the existing small population (12 individuals) is theoretically speaking not viable to survive into the future and due to the problems facing the Sanctuary, unless the Forest Department is keen on conserving the species in KWS for which management measures are recommended.

Keywords: Asian Elephant, Koundinya Wildlife Sanctuary, crop damage, human-elephant conflict, conservation

INTRODUCTION

Historically, Andhra Pradesh was not known to have elephants since the past 200 years (Syam Prasad and Reddy 2002). However, during the early 1980s, a small herd of elephants moved into the Kuppam and Palamaner forests of Chittoor district in Andhra Pradesh from the Hosur and Dharmapuri forests of Tamil Nadu, *c.* 60 km to its southwest. An assessment of the animals and their habitat (Sivaganesan and Bhushan 1986) found the habitat to be sub-optimal and postulated that the elephants had moved into the area due to drought in their normal distributional range and would move back into their original home during the next (favourable) monsoon. However, this did not happen, and later, more elephants migrated into the area during 1986 reportedly from the Bannerghatta National Park, Karnataka, which adjoins the Hosur-Dharmapuri forests. Some of the elephants that moved into Kuppam-Palamaner forests later dispersed north into the Sri Venkateswara Wildlife Sanctuary-National Park (Andhra Pradesh) and southwards to the Javadi Hills (Tamil Nadu).

The presence of elephants initially welcomed by the locals due to religious sentiments and ignorance of the problem potential of elephants changed rapidly with incidences of crop damage and human deaths. Attempts to drive them back into the the Hosur-Dharmapuri forests were unsuccessful. With time, the Andhra Pradesh Forest Department accepted the presence of elephants in their state and declared an area of 357 sq. km in the Kuppam and Palamaner forest areas as the Koundinya Wildlife Sanctuary (KWS). However, this and subsequent management measures did not help in improving the situation, and over the years, a total of 45 humans deaths, 24 elephant deaths and nearly 4,000 crop and property damage claims were registered with the Forest Department. The Bombay Natural History Society (BNHS) undertook this study from January 2005 to December 2005 (Daniel *et al.* 2006) primarily to assess the current situation of elephants and the habitat in KWS, and in this paper, we analyse the past and present human-elephant conflict in KWS and examine the mitigation measures adopted by the Forest Department and their effectiveness.

STUDY AREA

Koundinya Wildlife Sanctuary (12°39'-13°10' N; 78°29'-78°52' E; 357 sq. km), Chittoor district, Andhra Pradesh, falls within the hill ranges of the Eastern Ghats, a broken and discontinuous line of mountain range in peninsular India. KWS (Fig. 1) is linear in shape, running about 70 km north to south and the breath varies from *c.* 1 to 15 km. It has a periphery of about 224 km with 53 fringe villages and 8 enclosure villages. The Sanctuary comes under two ranges: Palamaner in the north and Kuppam in the south. Palamaner Range is divided into four blocks: Tekumanda, Musalimadugu, Mordana and Nellipatla. The Kuppam Range has six blocks: Naikaneri, Peddanaikdurg, Charagallu, Peddur Extension, Peddur and Kangundi.

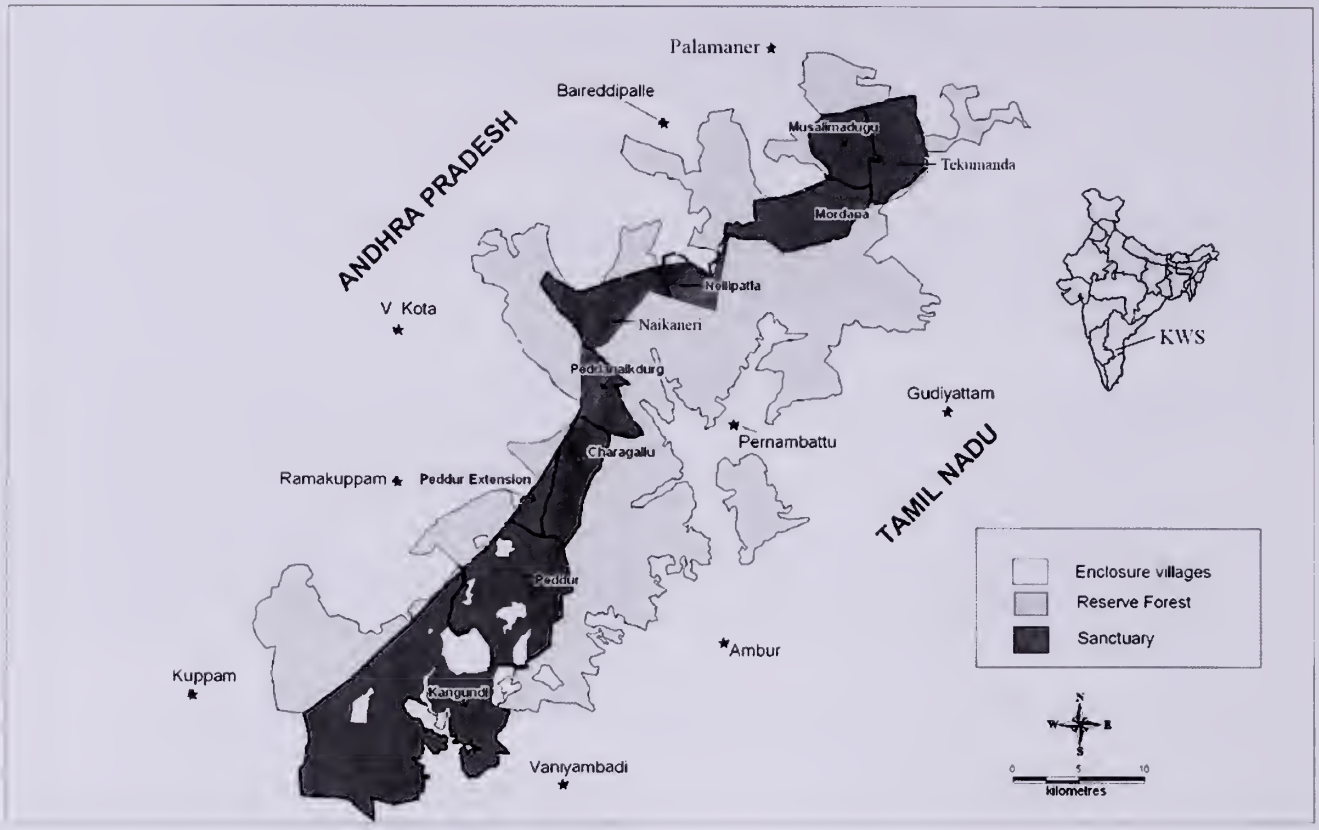

Fig. 1: Koundinya Wildlife Sanctuary: the study area

The water sources in the Sanctuary consists of the River Palar, its tributaries the Malattar (or Kaigal) and Koundinya, besides monsoonal streams. In general, water is available only at some places of the Palar and its tributaries during summer and water scarcity is severe during years of low rainfall. The other water sources in the Sanctuary comprises of natural or man-made ponds or lakes, most of which are largely situated at the outskirts of the fringe and enclosure villages.

Chittoor district receives rainfall from the South-West Monsoon (June-August) and North-East Monsoon (October-December), averaging about 380 mm and 410 mm respectively. However, the distribution of rainfall is uneven and the area is drought prone. The cold weather is from November to February with temperatures sometimes dropping to 10°C. Summer (March-May) is mild with maximum temperature of about 33°C (Anon. 2004).

The vegetation is predominantly of Southern Tropical Dry Mixed Deciduous (Champion and Seth 1968), comprising of trees such as *Hardwickia binata*, *Chloroxylon swietenia*, *Albizzia amara*, *Boswellia serrata*, *Anogeissus latifolia*, *Pterocarpus santalinus*, *Shorea* spp., *Diospyros* spp. and *Ficus* spp. The water courses are dominated by *Terminalia arjuna*, *Pongamia pinnata*, *Tamarindus indica*, *Mangifera indica*, and *Syzigium cumini*. However, the vegetation varies widely in different areas as a result of terrain, soil, impacts of grazing, fires, woodcutting, and history of exploitation. Due to the past history of exploitation for timber and fuel, most of the trees in the Sanctuary (except for minor forest produce species) have resulted from coppice growths or have got established in the last two to three decades, which explains their overall short stature. The exotic *Lantana camara* has invaded vast areas of the Sanctuary.

The major mammals reported from the Sanctuary are the Bonnet Macaque *Macaca radiata*, Hanuman Langur *Presbytis entellus*, Slender Loris *Loris tardigradus*, Leopard *Panthera pardus*, Striped Hyena *Hyaena hyaena*, Sloth Bear *Melursus ursinus*, Dhole *Cuon alpinus*, Jackal *Canis aureus*, Small Indian Civet *Viverricula indica*, Common Indian Mongoose *Herpestes edwardsi*, Indian Porcupine *Hystrix indica*, Indian Hare *Lepus nigricollis*, Indian Flying Fox *Pteropus giganteus*, Spotted Deer *Axis axis*, Four-horned Antelope *Tetracerus quadricornis*, Mouse Deer *Tragulus meminna* and Wild Boar *Sus scrofa*.

METHODS

Data on the past human-elephant conflict (HEC) in KWS was obtained from the Divisional Forest Department office at Chittoor and the two Forest Range offices at Kuppam and Palamaner. Apart from this, questionnaire surveys were

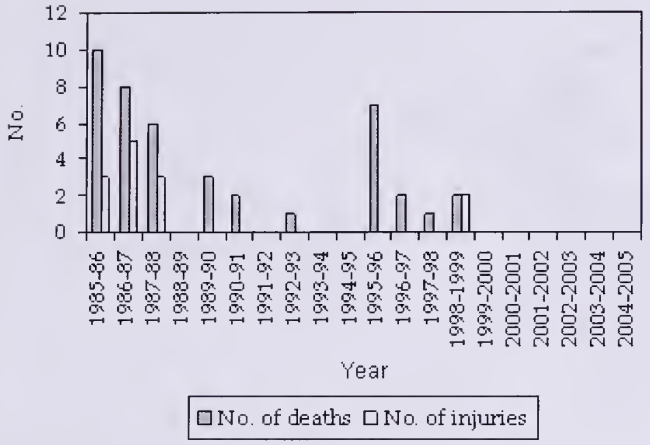

Fig. 2: Year-wise human death and injuries (1985-2005)

carried out in villages in and around the Sanctuary to have actual accounts of locals and information of unreported cases. A total of 45 fringe and enclosure villages in Andhra Pradesh and 18 bordering villages in Tamil Nadu were surveyed.

Information on the current HEC incidences was obtained through the above mentioned surveys and also from visits made to sites on reports received from villagers, Forest Department personnel and local newspapers. The data collected included the name of the village raided, crops/ property damaged, the extent of damage and the age-sex and group size of the raiding elephants. Measures adopted by the Forest Department (i.e., compensation, power fences, trenches, driving by elephant trackers) to prevent or mitigate human-elephant conflict and their effectiveness were assessed through actual observations and queries with affected people. Peoples' attitudes towards elephants were sought during the surveys and other field visits.

RESULTS

Past HEC

Human Deaths and Injuries: Being new to elephants and ignorant of their dangers and on how to deal with them, 45 people were killed and 13 injured in the KWS area from 1985 to 1999 (Fig. 2). The deaths and injuries resulted from people venturing to see elephants at village outskirts (a person even going to the extent of offering a coconut due to religious beliefs), while protecting crops against raiding elephants, when elephants passed through villages, and encounters on forest trails. With time, people recognized that elephants were dangerous and learnt to be wary and this resulted in a decline in deaths and injuries. However, encounters during crop raiding continued and this resulted in some deaths and injuries. With the capture of the bulls that were responsible for much of the conflict, no incidents of human deaths and injuries occurred after 1999. Though the identities of elephants responsible for deaths or injuries was not certain (as many occurred at night), enquiries with villagers revealed that bulls were generally responsible for many of the incidences. Most of the deaths and injuries that took place outside the forest areas (i.e., agricultural fields and villages) occurred in the late evenings or at night, while cases in forest areas occurred during the day and involved mostly herdsmen and woodcutters.

Elephant Deaths: Twenty-four deaths of elephants were reported between 1987 and 2003 in the Koundinya area. Reasons attributed for deaths include electrocution (54%), natural death (33%) and unknown causes (13%). Electrocution occurred primarily during crop raiding through contact with power lines laid by villagers to kill wildboar entering crop fields. A high number of deaths occurred between 1988 and 1993, and occurred mainly in the Kuppam Range, suggesting that even then (as is now) elephants ranged more in the southern part of the Sanctuary. Besides deaths given in Forest Department records, Sivaganesan and Bhushan (1986) obtained reports of a death of an elephant in the bordering Tamil Nadu area in the 1980s.

Crop and Property Damage: Forest Department records cite a total of 4,010 crop and property damage claims made from 1985 to 2004 and a total compensation amount of *c.* Rs. 2.57 million paid to the claimants. Our village surveys revealed that crop damage was earlier widespread all along the villages at the periphery of the reserve forests of Tamil Nadu that border the Sanctuary from Mordana in the north to Kothur (Nattarampalli) in the south-west (Fig. 3, see Fig.1 for more place names). Crop damage also occurred along the dispersal route between Krishnagiri and KWS. HEC has totally stopped in all areas of Tamil Nadu which border KWS since the last five years, except for the Sarangal area, which is located on the outskirts of the reserve forests that adjoin the Charagallu block, an area much frequented by elephants.

Present HEC

Human Deaths and Injuries: There were no human deaths or injuries during the study period, which is the case after 1999. The only report received of a near case of human-elephant encounter was of a herdsman, who reported having been chased off by a big bull when he came upon the herd in the Nellipatla block.

Elephant Deaths: Elephant deaths were not recorded during the study period.

Crop and Property Damage: Forty-four cases of crop damage from 17 villages were recorded during the study period (Figs 3, 4). The species raided were Ragi or Finger Millet (*Eleusine coracana*), Paddy (*Oryza sativa*), Maize

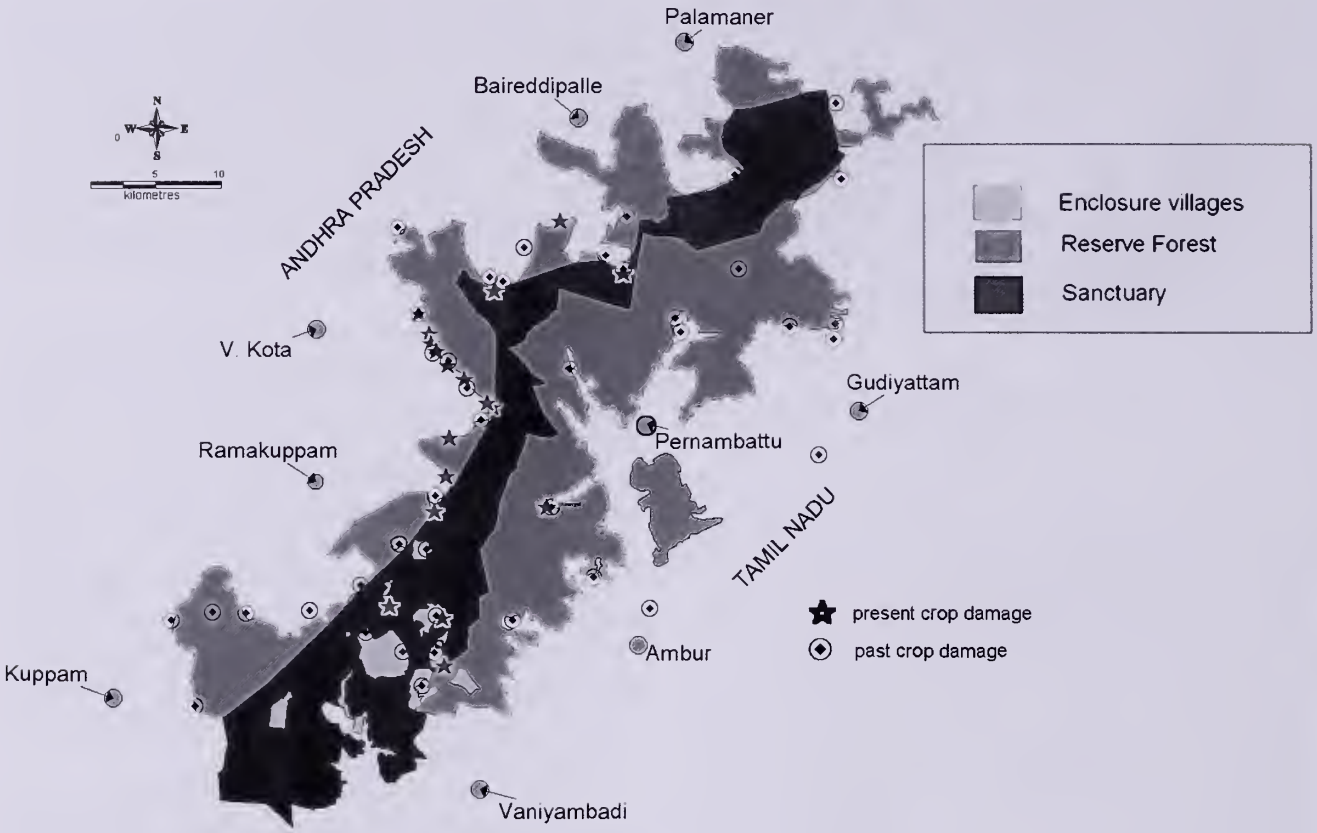

Fig. 3: Crop raiding pattern of elephants in the Koundinya Wildlife Sanctuary

(*Zea mays*), Sugarcane (*Saccharum officinarum*), Groundnut (*Arachis hypogea*), Banana (*Musa paradisiaca*), and vegetables comprising mainly of tomatoes and bean species (Table 1). Elephants damaged crops both by eating and trampling. Coconut (*Cocos nucifera*) and mango (*Mangifera indica*) were trees that were uprooted/damaged. In the case of coconut (5 trees), the tree was pushed down to feed on the foliage, thus killing the tree. The solitary bull (sometimes accompanied by the subadult bull from the herd) was responsible for 59% of the raids and the (single) herd for the rest. Damage to property recorded during the study period consisted of a crop owner's watch-hut (1 case) and irrigation pipes (2 cases).

Table 1: Crop species damaged by elephants and the extent and nature of damage

Crop	Area of field (ha)	Area damaged (ha)	Eaten/ Trampled
Ragi (*Eleusine coracana*)	16.74	4.1	E
Paddy (*Oryza sativa*)	10.87	3.03	E
Sugarcane (*Saccharum officinarum*)	7.72	0.58	E
Maize (*Zea mays*)	2.57	1.82	E
Bean species	1.96	1.1	T
Tomatoes (*Lycopersicum esculentum*)	1.76	1.5	T
Fodder grass species	0.55	0.18	E
Groundnut (*Arachis hypogea*)	0.40	0.07	T
Total	42.57	12.38	-

Note: Bananas *Musa paradisiaca* (3 fields), Coconut *Cocos nucifera* (5 trees) and Mango *Mangifera indica* (1 tree) were the other species that were damaged/killed.

Peoples Attitude to Elephants

The majority of the villagers (n=65) interviewed during the surveys said that they were averse to elephants in their areas due to the dangers posed and resulting restriction of their movements in forests. A small number (15) opinioned that they did not mind or even liked elephant presence in the areas as long as HEC was kept under control. Three respondents (including one whose crop field had just been raided) said the presence of elephants was welcome as elephants brought rains (as is the locals' belief).

Mitigation Measures

The strategies adopted by the Forest Department to mitigate human-elephant conflict (HEC) in KWS were/are:

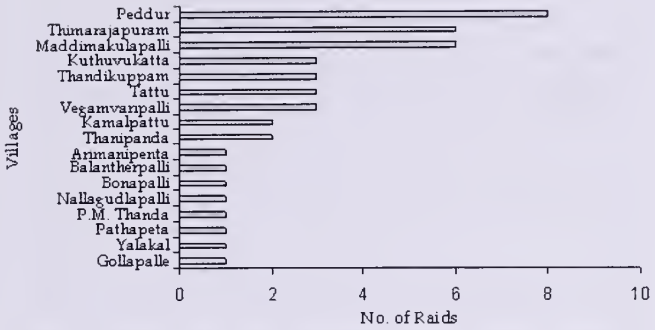

Fig. 4: Village-wise raids recorded during the study period

Electric fence: The Forest Department initially opted for electric fences, and between 1989 and 1992 laid a linear stretch of fence from the northern to southern end of the Sanctuary, positioned between the border of the Sanctuary and the reserve forests of Andhra Pradesh. This fencing was a failure since it was in the interior areas of the forest making maintenance and monitoring difficult, and also due to theft of fence material, including the supporting granite posts. Learning from this mistake, the Department started erecting fences in 1989 around enclosure villages and the edges of fringe villages. Till December 2005, about 100 km of fence had been erected with a balance of 60 km to be completed. Cooperation of villages was sought to ensure that the fence material was not stolen. The fences, except for the recently erected fence around the 'elephant camp', are solar-powered 4-strand fences supported by granite posts. Only the fencing around the elephant camp is the standard 7-strand fence with steel posts that is more widely used nowadays.

Removal of problematic animals: Removal of elephants (all bulls) by capture was necessitated when these animals took to manslaughter and/or became habitual crop-raiders. Some animals that dispersed out of the Sanctuary were also captured. A total of 6 bulls were captured in KWS and outside areas, and sent to zoos. One animal died during the capture operation.

Driving elephants from human habitation: The Forest Department has a team of 6 'elephant trackers' belonging to the tribal Yanadi community whose work is mainly to drive elephants off human habitation areas whenever reported with the help of crackers. Though never being familiar with elephants in the past, the team has gained experience over the years and is quite adept at this task without any loss to life or injuries till date.

Monetary compensation: Monetary compensation is an indirect method adopted by the Forest Department to mitigate HEC. Amounts are fixed (with revisions as felt necessary) for different HEC cases. The amount paid for manslaughter is currently Rs.1,00,000 up from Rs.10,000 during the 1980s. Assessment of crop damage is made by inspection of fields by the Forest Department along with officials of the Agricultural Department and the claimants. Locals interviewed said that adequate monetary compensation is a satisfactory solution for crop or property loss, but cannot compensate for the loss of human life. The problems cited regarding monetary compensation (a) Inadequate compensation (b) Time, procedures and resources needed to lodge complaints, and (c) Delays in getting compensation.

DISCUSSION

Human-elephant conflict in the KWS area was severe in the past, but has shown a marked decline in the past few years, especially with regard to manslaughter. There are a number of reasons for the decline in HEC. Two important factors are the fall in elephant population from about 80 to 12 individuals and the settling down of the current population (contra exploratory nature of the earlier herds and bulls). Another equally important contributory factor was the removal of problematic bulls. Most of the kills of humans in KWS were by tuskers, which is the trend in southern India where 80% of the manslaughter reported was by bulls though they constitute less than 10% of the total population (Sukumar 1991). Appaya (1992) reported that almost all the 56 problematic elephants that were translocated out of the isolated pockets of forests into larger forest tracts in Karnataka consisted of bulls. Sukumar (1991) reported that in less than a decade HEC has significantly reduced in the Chamarajanagar and Satyamangalam regions owing to poaching of bulls for tusks. Some bulls are inherently aggressive (especially during musth) and turn into habitual killers (Sukumar 1989; Cheeran 2002), and similarly, some of the captured bulls in KWS were reported to be wanton killers. One extremely large bull which was captured due to HEC problems, and which died soon after, is believed to have been responsible for many of the manslaughter cases in KWS. Another reason for decline in manslaughter is that the locals are now aware of the dangers of elephants, unlike earlier where whole villages would venture to see elephants that came near human habitation. Conversely now, herdsmen and woodcutter avoid venturing into forests areas on reports of elephant presence and quickly run away or take to the shelter of large trees on approach of elephants.

Bulls are also well-known to raid crops more frequently than family herds (Santiapillai and Ramono 1993; Appaya 1992; Daniel *et al.* 1995; Sukumar 1989, 1991). However, though the frequency of raids by males was more, the extent of damage caused by bulls and herds was not statistically different as the damage caused by a herd collectively is more than a bull's (Balasubramanian *et al.* 1995). Studies by

Baskaran and Desai (1996) revealed that only specific clans and males raid crops, which suggest that removal of crop-raiders can eradicate or mitigate crop damage. However, it has to be borne in mind that removal of bulls from the population would adversely impact breeding. At present, there are only two adult bulls (one which stays with the herd) in KWS, besides a subadult and juvenile bull, and it may just be a matter of time before they start to create problems. In fact, the elephant trackers anticipate this to happen in future especially in the case of the adult lone bull, which is becoming bolder.

Electric fences are regarded to be generally effective against elephants but constant maintenance is important to its success (Seidensticker 1984; Sukumar 1986, 1989, 1991; Balasubramanian *et al.* 1995; Daniel *et al.* 1995; Daim 1995; Santiapillai 1996). Fences backed by additional protection and stakeholders support (as in the case with privately owned plantations) were found to be more successful (Balasubramanian *et al.* 1995; Nath and Sukumar 1998; Chauhan and Chowdhury 2002). In non-privately owned fences, as is the case with KWS, people do not feel responsible for their maintenance even thought it benefits the village as a whole. However, it is difficult to stop elephants from raiding crops once agriculture becomes the principal land use in the vicinity of elephant reserves (Santiapillai and Ramono 1993) and since elephants learn to get through electric fences (Seidensticker 1984; Sukumar 1989; Santiapillai 1996) irrespective of design criteria (Thouless and Sakwa 1995; Nath and Sukumar 1998). In KWS, given the dynamic nature of the whole situation where elephant numbers have changed and problematic elephants captured (and killed by electrocution), it is difficult to attribute changes in crop raiding intensity to the electric fence. However, HEC data collected during this study shows that elephants raided crops even where fences exist by pushing down and breaking the exposed granite posts. The opinion gathered from villagers is that power fences do not really act as a barrier for crop raiders, but it does deter elephants from entering fenced areas if the animals are not intent on crop raiding.

As for KWS, while the single long fence failed, the current approach to fencing of one or more villages is more practical even though it has not stopped elephants from totally raiding crops. The causes of failures basically are (a) lack of stakeholder involvement where the villagers do not see the fence as their own and do not help in monitoring and maintenance (b) absence of participation by all stakeholders in the erection of fences resulting in breakage to enter forests for fuel wood, cattle grazing, etc., and (c) poor construction and use of unsuitable material, e.g., granite posts. As fences guarded at night are more secure than unguarded ones, some efforts must be made to guard fences, especially when elephants are reported near villages. Another important aspect that people and managers need to be aware and accept is that fences do not provide 100% solution and they only reduce the intensity of conflict. Hence, breakages by elephants should not be viewed as failures but rather looked upon as normal as long as the overall damage is reduced. However, given the poor quality of the existing habitat, the 'fencing off' of villages may result in elephants resorting to greater number of break-ins to get at crops in the event that natural food is not adequate, so habitat protection and improvement measures are an integral part of the HEC mitigation.

With regard to the drives from human habitation areas by elephant trackers, this strategy gives the false appearance of being successful mainly due to the small elephant population. The manpower requirements for this strategy would be huge and difficult to implement if the elephant population was larger with more herds and bulls operating in the area. The drives in fact only result in transferring the problem from one village to another or/and result in the animals coming back to the village after a gap of a few days. Elephants soon recognize such psychological bluffs and get accustomed to them (Santiapillai 1996). The drives are now taking longer with the animal retreating into the forests more leisurely. The elephant trackers in KWS report that the lone bull is now quite habituated to the drives and occasionally stands its ground and fling things at them during drives from crop fields. However, the presence of the trackers and drives gives a psychological boost to the affected villagers.

Considering all the above mentioned factors, it appears that a combination of decline in population, settling down of herds, removal of bulls and people's awareness are largely responsible for the decline in HEC rather than the effectiveness of the current HEC mitigation measures, i.e., power fences and driving by elephant trackers. A number of factors are responsible or act as catalysts for HEC in KWS as follows:

1. The small size of the Sanctuary, its linear shape and the extensive interface of forest and human habitation ensures that elephants encounter human use areas in every direction of movement.

2. HEC would be more severe when elephants start operating in a new area as they are unfamiliar with the area, resulting in constant encounter with people. People are also unfamiliar with elephants and are not geared to address HEC. Most fields have no crop protection and even when crop raiding starts, people do not know how to protect their crops from elephants unlike in areas where people are habituated to elephant depredations.

3. Elephants due to their large size and bulk food requirements are far-ranging mammals and radio-telemetry

studies show their home ranges to be as large as 500 sq. km for clans; 623 sq. km and 530 sq. km for cows, and 374 sq. km and 210 sq. km for bulls (Baskaran *et al.* 1995; Daniel *et al.* 1995), and thus are more likely to come into contact with human habitation and take to crop-raiding than other mammals, and especially as elephant habitats shrink and/or get degraded (Sukumar 1986, 1989; Daniel *et al.* 1995; Nair 2004).

4. The general scarcity of water in forest areas in summer (especially during low rainfall years) and its availability in irrigation tanks near human settlements act as catalysts for crop-raiding. Many of the check-dams constructed to supplement water resources for elephants are at the edges of the forest instead of interior areas. These water sources attract elephants, and in such situations, crop-raiding occurs as a consequence of the need for water, which for elephants is significant at around 200-250 litres/day (Sukumar 1989; Cheeran 2004). Water sources acting as catalysts for crop raiding have been reported by other workers (Seidensticker 1984; Sukumar 1989, 1990; Ramesh Kumar 1994; Daniel *et al.* 1995).

5. Habitat loss or degradation through grazing by livestock and wood-cutting by locals, and also the decline of food plants due to over-utilization by elephants due to 'pocketing effect' (especially applicable to small sanctuaries) and loss of corridors to adjoining forest tracts also results in crop-raiding. In such situations, feeding habits soon become environment destroying activities as migratory routes are blocked and forage supply diminishes (Wing and Buss 1970). Villages and crop fields bordering such forests will face more HEC due to the suboptimal resources (Sukumar 1986; Daniel *et al.* 1995). It is estimated that prime elephant ranges have shrunk by 20-25% in southern India within a century and fragmentation has brought elephants closer and in conflict with people (Sukumar 1989, 1990).

6. Even if the above mentioned problems do not exist, elephants will continue to raid crops since cultivated species are highly nutritious, more palatable and less toxic than their wild counterparts and require less feeding effort due to single species dominance (Sukumar 1985, 1989, 1990). Though not much highlighted in studies, crop-raiding in grass deficient areas like KWS could be more related to requirements of grass in the diet than other factors considering that Poaceae (Graminae) species such as finger millet are preferred during crop-raids.

CONCLUSION

Other than the requirements of extensive landscapes for survival, conservation initiatives become more difficult for elephants due to the problem of HEC. The Indian Government annually spends about Rs. 100-150 million on measures to control crop depredation and ex-gratia payment to the victims of depredation. HEC not only breeds hostility among the locals towards elephants but also towards Forest Department staff (Bist 2002). In the case of KWS, most of the locals living at the borders of the Sanctuary are poor and cannot be expected to live with elephants in their vicinity (which were not there earlier), suffering ensuing economic losses and tolerating the inconveniences and threats to lives and livelihoods.

As discussed in detail earlier, preventing crop raiding in KWS is extremely difficult due to the small size of the Sanctuary, its linear shape with an extensive interface of forest and human habitation areas, scarcity of water in summer and compounded by its availability around village surroundings, habitat loss and degradation through human related factors and 'non-sustainable use' of food plants by elephants due to their 'pocketing' in KWS with the loss of corridors and adjoining forests. Due to these factors and since the long-term survival of the small population of elephants in KWS is bleak, the practical solution to tackle HEC would be the removal (translocation or capture for zoological parks) of elephants from the Sanctuary, as has been suggested by others for sites facing pressures and having small populations (McKay 1973; Sukumar 1986,1989; Santiapillai 1996). However, if the Andhra Pradesh Forest Department is keen on the conservation of the elephants, which are the *raison d'etre* of the Sanctuary, then besides attending to some of the lacuna in HEC mitigation discussed earlier, the following are recommended:

Protection of habitat: Protection of habitat would be the key factor in improving the status of elephants in KWS. If it is difficult to stop fuel wood collection, cutting of small timber, fires and cattle grazing, then it will be impossible to improve the situation for the existing population, let alone a much larger one needed for long-term conservation.

Collaboration with the Tamil Nadu Forest Department to protect border areas: The eastern and south-eastern borders of the Sanctuary are contiguous with the reserve forests of Tamil Nadu. These reserve forests face major threats for fuel wood from the people of the plains and these pressures are progressing into the Sanctuary areas. Hence, the officials of the Sanctuary need to collaborate with the Tamil Nadu Forest Department to put a check on the pressures and disturbances in these areas.

Inclusion of reserve forests into the Sanctuary: As the Sanctuary is small and narrow, and due to its insularity, the adjoining reserve forests of Andhra Pradesh on its western border should ideally be incorporated into the Sanctuary to enjoy the enhanced benefits that sanctuaries have compared

to reserve forests. Many of the reserved forest areas are already being used by elephants as there are no barriers to stop them from entering these areas. However, the inclusion would have an impact only if the change in status of the land results in greater protection and improvement of habitat in a manner suitable for elephants.

Habitat Enrichment: A number of habitat enrichment plots of food plants for elephants have already been established by the Forest Department. Most of them are at the outskirts of villages, and hence, are either avoided by elephants or act as catalysts for human-elephant conflict. As browse availability appears to be sufficient and it is grass availability that is scarce in the Sanctuary, planting of browse species is unnecessary and instead grass or bamboo plots could be established. Areas having alluvial soils or moist conditions should be preferred as these give rise to more palatable grass species. However, grass availability is best addressed through reduction/stopping of cattle grazing as there would be little use in trying to grow grass if cattle grazing persists. Additionally, habitat enrichment would be futile if the other factors responsible for habitat degradation cannot be addressed.

Creation of water sources inside the Sanctuary: One reason for human-elephant conflict in KWS is due to the scarcity of water during summer compounded by its availability near human habitation. For this reason, we suggest construction of a few more water resources in the interior forest areas and development and protection of important water sources. Posting of Forest Department watchers at some of the important sites during summer is recommended as poachers of other wildlife tend to camp around waterholes during summer. Construction of water resources is generally discouraged since it causes artificial increase in elephant pressures on vegetation around waterholes, especially during the dry season (Daniel *et al.* 1995; Santiapillai *et al.* 1995; Sukumar 1989), but is essential in Koundinya as water resources tend to be scarce during low rainfall years causing elephants much hardship and encouraging HEC. These negative impacts of waterholes could be lessened if they are well distributed (see Seidensticker 1984). Additionally, artificial supply of water has been found to give rise to relatively small and stable elephant home ranges (Whyte 2001), which could prevent wandering of the KWS elephants into border areas and thus reduce human-elephant conflict.

Planting of alternative crops: The Forest Department, in consultation with the Agriculture Department, could encourage the villagers to grow crop species that are not palatable or less preferred to elephants such as chillies, lemon and mulberry. Providing incentives/subsidies/loans to the villagers and facilities like drip irrigation, help in transport of goods and finding buyers for the produce will be required to achieve this objective as villagers tend not to change unless help and facilities are offered.

Monetary Compensation for HEC: There is a need to have simple and clear procedures for registering, evaluation and payment of claims, so that people become aware of these and transparency is established. As most of the affected are illiterate and subsistence farmers, and tend to be wary of officialdom, payment of compensation claims in the field in the presence of village officials would be a helpful solution.

Eco-development: With the pressures facing the Sanctuary for its natural resources from bordering villages, it appears unlikely that the Sanctuary can survive into the future unless it receives the support of local communities. For this, the conditions of the local villagers need to be improved and their dependence on forest resources reduced or stopped by providing alternatives. There are already two schemes in KWS working towards this objective, the Vana Samrakshna Samithi (VSS) and the Eco-Development Committee (EDC) both funded by the World Bank and coordinated by the Forest Department. The focus of these schemes are to uplift the standard of life of the villagers by providing support in improvement in agriculture, animal husbandry and setting-up small scale or cottage industries; providing employment through soil and moisture conservation works and construction of checkdams; introduction of alternative fuel (biogas) and fuel saving devices (*choolas*); harvest and processing of minor forest produce on a sustainable basis; and augmentation of fuel wood and fodder in community lands. However, judging from the pressures and disturbance recorded in the forest during the study, it appears that these schemes have still not achieved their objectives as far as people's dependence or exploitation of forest resources is concerned. As increase in human population will put more pressures on the success of these schemes, family planning should be included as an important component of these programmes. Eco-development is especially vital for small sanctuaries with villages at their fringes and a growing population (as in the case of KWS), and it is important that schemes like the VSS and EDC are successful if the Sanctuary is to survive into the future.

ACKNOWLEDGEMENTS

This project was possible through funding by the U.S. Fish and Wildlife Service (USFWS). In the USFWS, we are indebted to Mr. David Ferguson, former SFC Coordinator (Retd.), Division of International Conservation for his suggestions while formulating the project and to Dr. Karl A.K. Stromayer and Dr. Meenakshi Nagendran, former and present

Project Officers of the Asian Elephant Conservation Fund respectively (and their supporting staff) for support and cooperation. The Andhra Pradesh Forest Department kindly gave permission to undertake the studies in their state and we thank the officials and personnel in the study area for the help and cooperation rendered.

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POPULATION STATUS AND HABITAT USE OF WILD PIGS *SUS SCROFA* IN KEOLADEO NATIONAL PARK, BHARATPUR, RAJASTHAN, INDIA

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The Indian wild pig population in Keoladeo National Park, Bharatpur was studied from January 2007 for six months. A total of 78 groups were sighted during the entire study period. Overall density was estimated to be 15.7 wild pigs / sq. km (%CV=17.99). The present density estimates were seven times that reported by Haque in 1990. Pellet group density was found to be significantly different ($F = 6.894$, $df = 5$, $P < 0.001$) among all the habitats, with the highest in short grassland open area (522 pellet groups / ha) and least in tall grassland savannah (20 pellet groups / ha). Male to female ratio was calculated to be 1:1.01 which was in coherence with the studies conducted elsewhere. Absence of predation pressure was attributed to be one of the key factors in determining the sex ratio at the time of maturity. Female to young ratio was 1:2.85, which represents a normally growing population of Wild pig in the Park. Mean group size exhibited by the population was (3.79 ±0.44). Larger groups were found in habitats with abundant food supply, whereas smaller group were in poor forage sites. Short grassland open area and mixed habitat were used much more in proportion to their availability, and tall grassland savannah and *Prosopis juliflora* thickets were used less than the availability. Grass density, quality forage, dense cover and easily accessible water source were suggested to be the dominant factors in determining the habitat utilization patterns of the Wild pig population in Keoladeo National Park.

Key words: Density, forage sites, groups, habitat utilization, Keoladeo National Park, predation pressure, quality forage, Wild pig

INTRODUCTION

The Indian Wild pig *Sus scrofa* is one of the most widely distributed mammals in the world, with its native range extending from Western Europe to south-east Asia (Bratton 1975; Massei and Genov 2004; DEFRA 2005). In recent decades, their number has increased worldwide (Morini *et al.* 1995; Baubet *et al.* 2004). The absence of predation pressure can be attributed as one of the major causes for successful spread of the species worldwide (Genov 1981; Saez-Royuela and Telleria 1986). It is very active as an opportunistic feeder and its diet varies among different habitats and geographical distributions, which surely contribute to the widespread distribution of the species (Ashby and Santiapillai 1998; Baubet *et al.* 2004; Massei and Genov 2004). Wild pigs are known to have a substantial environmental impact and affect many ecosystem components, being a key species in the trophic chain (Galvano-Alves 2004; Massei and Genov 2004). However, more importantly, their populations are known to damage crops and vegetation (Lacki and Lancia 1983; Scarcelli *et al.* 2004). Consequently, their populations are under pressure predominantly due to human-animal conflict, which needs to be controlled in a way that both management and conservation may go hand in hand and their survival may not be threatened in future. But before doing this, the management authorities should have some baseline data, such as population size, predation pressure, and habitat use on the species. Also, equally important is an investigation of various factors governing its distribution.

Till date, several studies have been conducted on ungulate species in the study area and throughout the country. Wild pig populations have, however, faced a continuous negligence for some reason. The role of Wild pigs in the ecosystem of Keoladeo National Park is not known; hence, we decided to carry out the studies pertaining to its population dynamics, composition, and habitat utilization patterns.

STUDY AREA

The study was conducted from January 2007 for a period of six months in Keoladeo National Park, Bharatpur. This 29 sq. km Park falls in the semi-arid biogeographical zone (Rodgers and Panwar 1988). It is a Ramsar Site, World Heritage Site, and Important Bird Area. The average elevation of the Park (Fig. 1) is about 174 m above sea level. Topographically, it is more or less flat with a gentle slope towards the centre forming a depression, total wetland area being about 8.5 sq. km. The Park is characterized by a sub-tropical climate with rainfall ranging from 283.7-481 mm. The summer temperature in the area ranges from 20.8-41.6 °C.

The vegetation of the area is a mixture of xerophytic and semi-xerophytic species. The classification of distinct

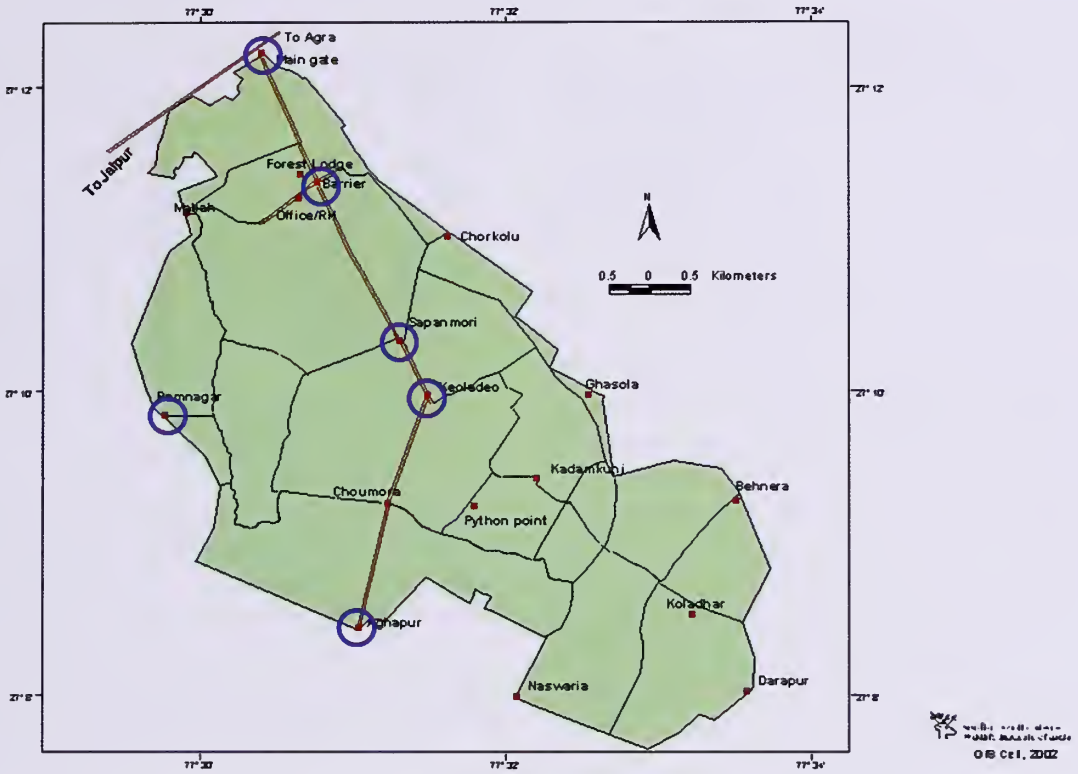

Fig. 1: Study area: Keoladeo National Park, Rajasthan

habitat types is quite difficult owing to the widespread distribution of *Prosopis juliflora* in the entire Park area. However, based on the present study, the general floral composition of the study area is characterized as: (1) **Wetland** with aquatic vegetation mainly consisting of emergent, rooted floating, submerged and free floating plant species (Vijayan 1987). (2) **Woodland** with *Mitragyna parvifolia*, *Acacia nilotica*, *Zizyphus mauritiana* and *Syzygium cumini* as the dominant species and a dense shrub storey comprising mainly of *Prosopis juliflora*. (3) **Mixed habitat** consists of irregular distribution of trees diffused with thorny shrubs in the undergrown layer. The ground is covered with short grass species like *Cyperus rotandus* and *Sporobolus* spp. (4) **Dried Wetland** resulting from water scarcity in the Park has *Paspalum disticum*, *Parspaladium* spp. and *Cyanodon dactylon* as dominant grass species and exhibits maximum number of herbs, i.e., *Amaranthus viridis*, *Euphorbia aubiculata*, *Melilotus indica*, (5) **Grassland** of three types: (a) Tall grassland having *Vetiveria zizanioides* and *Desmostachya bipinnata* as the dominant species. (b) Savannah, with scattered distribution of some trees. (c) Short grassland having continuous layer of short grasses, such as *Cyanodon dactylon* (6) *Prosopis juliflora* dominated area in the Park is about 15-17 sq. km. It consists of dense to discontinuous thickets of *Prosopis juliflora*.

METHODOLOGY

The Wild pig density and its distribution in Keoladeo National Park were studied using two methods. Line transect method (Burnham *et al.* 1980) was used to estimate the overall density in the study area and pellet group count method was used to calculate the density in each habitat separately. Indirect evidences were used for habitat-wise density estimation as direct sightings in some habitats were less than forty, thus not fulfilling the assumptions for the software DISTANCE. In all, six transects, one laid in each habitat based on reconnaissance surveys, were monitored twice a day during 0600 to 0900 hrs and 1700 to 1900 hrs. The Wild pig being shy, the activity could not be recorded on trails, hence transects were laid passing through the interior of the blocks. Transects were surveyed carefully in order to avoid sudden disturbances. Frequent pauses were made to listen for sounds of Wild pig during the transect surveys.

To study the habitat features, circular plots of 10 m radius were laid in each habitat and the habitat characteristics were then correlated with the Wild pig density. Plots were laid 50 m away on either side of transect to avoid sampling of disturbed vegetation. Within the 10 m radius plots, circular plots of 3 m radius were also laid for pellet counts to estimate the habitat-wise density. A total of 280 vegetation plots were

laid in different habitat types of the study site with an average of 40-44 plots in each habitat.

Data was analyzed using DISTANCE version 5.0 beta 5 (Thomas *et al.* in press). The model half-normal was selected as the most appropriate model for estimating density on the basis of minimum AIC value. Density, encounter rate, effective strip width and mean group size were derived using the software. Pellet group density in each habitat was calculated and tested for significant differences in their mean by using one-way ANOVA. Species density for each habitat was calculated using appropriate formula. Species diversity and richness were calculated using Shannon-Wiener Species Diversity Index (H') and Margelef's Index (RI) respectively by SPECDIVER; a DOS-based modified module of STATISTICAL ECOLOGY. To assess the habitat utilization patterns of Wild pig, the statistical program PREFER was used (Gupta and Prasad 1992), and the preferences and avoidances for each habitat were examined by means of Bonferroni z-intervals and confidence intervals (Neu *et al.* 1974; Byers *et al.* 1984). To assess the difference in habitat utilization of Wild pig in different months of the study period, Habitat Preference Index (HPI) (Aspinall *et al.* 1998) was calculated based on the encounters in a particular habitat in different months. To extract the correlation among different habitat variables and Wild pig pellet group densities Pearson's Product Moment Correlation Coefficient was performed.

RESULTS

Density

The overall density of Wild pigs in Keoladeo National Park (KNP) was found out to be 15.7 Wild pig / sq. km (%CV= 17.99). The effective strip width was 61.33 ±4.8 m (%CV=17.99). Mean pellet group density of Wild pig was highest in short grassland open area 522 pellet groups / ha, followed by mixed habitat 307 / ha, dry wetland 230 / ha, *Prosopis* thickets 40 / ha, and tall grassland Savannah 20 / ha. Pellet group density varied significantly across different habitats ($F = 6.894$, $df = 5$, $P < 0.001$).

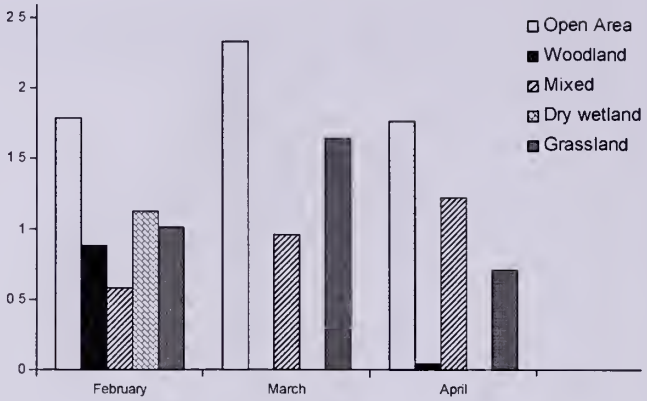

Fig. 2: Habitat Preference Index (HPI) of Wild Pig in different habitats in KNP

Population composition

Out of the total 293 individuals sighted, which includes all the replicate sightings of wild pigs during all the monitorings repeated for all the transects, 14% were adult boars (males), 15% were adult sows (females), 18% were subadult boars, 3% subadult sows and 39% were young ones. 11% of the population remained unsexed. The adult male to female ratio was 1:1.01, subadult male to female ratio was 6:1, while female to young ratio was calculated to be 1:2.85.

Table 1: Results of habitat preference or avoidance (using PREFER Software) by Wild Pig in Keoladeo National Park

Habitat	Total Area (sq. km)	Observed Use	Expected Proportion Use (Pi)	Bonferonni intervals
SGOA	4.405	157	0.152	*** 0.289>(*Pi*)<0.407
Woodland	1.678	42	0.058	** 0.057<(*Pi*)<0.129
Mixed	5.203	168	0.18	*** 0.312>(*Pi*)<0.433
Dry Wetland	4.196	52	0.145	** 0.076<(*Pi*)<0.155
Tall Grassland Savannah	6.084	17	0.21	* 0.014<(*Pi*)>0.061
Prosopis juliflora Thickets	7.343	15	0.254	* 0.011<(*Pi*)>0.056

* Avoided
** Used in relation to availability
*** Preferred
Values in parenthesis represent the Bonferroni Confidence Intervals
SGOA; Short Grassland Open Area

Group size

During all the replicate monitorings of all the six transects laid in the entire study period, 78 groups of Wild pigs were detected with a mean cluster size of 3.79 ±0.44, where the mean group size in short grassland open area was estimated to be 4.5, in woodland it was 2.0, in mixed habitat 4.2, for dry wetland 5.25, and 2.0 for tall grassland savannah. Rooting was the most frequent activity (41%) exhibited by the larger groups of wild pigs.

Habitat use

The utilization of short grassland open area habitat and mixed habitat was found to be more in proportion to their availability. Woodland and dry wetland were used in accordance with the availability, whereas tall grassland savannah and *Prosopis juliflora* thickets were avoided (Table 1).

Correlation analysis for pellet group density of wild pig and different habitat variables exhibited a significantly positive relationship with grass density ($P < 0.05$), shrub cover ($P < 0.05$), chital density ($P < 0.05$), blue-bull density ($P < 0.05$), hare density ($P < 0.01$) and jackal density ($P < 0.05$), while a significantly negative correlation was seen with canopy cover ($P < 0.05$), tree height ($P < 0.05$), GBH, i.e., girth at breast height ($P < 0.01$), bare ground ($P < 0.01$) and distance from water source ($P < 0.01$) (Table 2).

Table 2: Pearson's product moment correlation between pellet group densities of Wild Boar in different habitats with different habitat variables in Keoladeo National Park

S.No.	Habitat Variables	Pearson's coefficient correlation value with Wild pig pellet group densities
1	Tree Cover	- 0.098
2	Canopy Cover	- 0.126*
3	Tree Height	- 0.155*
4	GBH	- 0.190**
5	Tree Density	- 0.104
6	Tree Diversity	- 0.111
7	Tree Richness	- 0.107
8	Shrub Cover	0.265*
9	Shrub Height	0.169
10	Shrub Density	0.073
11	Shrub Diversity	0.039
12	Shrub Richness	0.120
13	Grass Height	0.089
14	Grass Density	0.142*
15	Grass Diversity	0.119
16	Grass Richness	0.050
17	Litter Cover	0.037
18	Bare Ground	- 0.261**
19	Grass Cover	0.089
20	Herb Cover	0.083
21	Chital Density	0.143*
22	Nilgai Density	0.134*
23	Cattle Density	0.017
24	Hare Density	0.317
25	Jackal Density	0.122*
26	Distance from water source	- 0.284**

Significance level
**= 0.01
*= 0.05

Table 3: Habitat Preference Index (HPI) for Wild Pig in different habitat types

Month	Short grassland Open Area	Woodland	Mixed	Dry wetland	Tall Grassland Savannah
February	1.790	0.88	0.58	1.126	1.01
March	2.332	0	0.96	0	1.644
April	1.765	0.042	1.224	0	0.711

Habitat preference index (HPI) (Allen 1983) was highest for short grassland open area for the three months (February, March and April). In February dry wetland, in March tall grassland and in April mixed habitat was preferred after low grassland open area (Table 3; Fig. 2).

DISCUSSION

Density

The estimated density of wild pig population, i.e., 15.7 individuals / sq. km in the study area suggests a consistent growth pattern as it is seven times that reported by Haque in 1990 (2.24 individuals / sq. km), though the study was for a period of three years and was not specifically focused on wild pigs. The growth exhibited by the population could primarily be attributed to the absence of predation pressure in KNP, as is the case exhibited worldwide (Genov 1981; Saez-Royuela and Tellaria 1986). Wild pigs are capable of rapid population increases due to early onset of puberty, their ability to have large litters and potential to breed more than once per year (Baber and Coblentz 1987). They are also known to have the highest reproductive rate among ungulates (Massei and Genov 2004). Moreover, being an opportunistic feeder, a generalist and an adaptable omnivore, Wild pigs are capable of altering and adjusting its diet in accordance to the availability in the surrounding environment (Henry and

Table 4: Growth trends in ungulate population during the last few years in Keoladeo National Park

Species	Density (sq. km) (Haque, 1990)	Density (sq. km) (Present study, 2007)
Wild Pig	2.24	15.73
Chital	9.79	86.9
Nilgai	7.0	16.8
Sambar	0.75	0.54

Conley 1972; Massei and Genov 2004). High fecundity and early onset of maturation are other factors contributing to an astonishing growth in the wild pig population (Coblentz and Bouska 2004). Increase in the species' population in the countries overseas, during the last few decades has also been attributed to socio-economic changes. Socio-economic changes are known to result in improved environmental conditions for the species, variations in the dominant crop types, limited hunting, additional food and climatic conditions (Genov 1981; Erkinaro *et al.* 1982; Saez-Royuela and Telleria 1986).

On considering the growth trends of other ungulate species in Keoladeo National Park (KNP), during the last two decades, a positive interaction appears between the Wild pig population and other ungulate species (Table 4). Interspecific competition seems to play no inhibitory role in the growth of Wild pig population inhabiting the Park. Also, in the absence of natural predators boar numbers are limited only by the availability of resources (such as food and shelter), or by human intervention (DEFRA 2005). Thus, the rapid growth exhibited by the population is not very surprising.

The highest mean pellet group density in short grassland open area may be due to several factors, including quality forage, easy access to water source and dense thickets to hide and seek shelter (Kearney and Gilbert 1976). High density in mixed habitat may also be due to abundant food supply, water accessibility, high cover and least disturbance, whereas low densities in *Prosopis juliflora* thickets and tall grassland savannah can primarily be attributed to unavailability of food.

Population composition

The estimated male to female ratio of wild pig population in Keoladeo National Park (1:1.01) is similar to that of Pakistan (1:0.75) (Ahmad *et al.* 1995), Jaldapara (1:1) (Schaller 1967) and Lithuania (1:1.04) (Janulaitis 2003). But, the observed trend goes against the normal female biased sex ratio, exhibited among all animals in general, the males being more prone to predation and environmental stress. The equal male to female ratio from birth to maturity amongst Wild pigs could primarily be attributed to the absence of a natural predator. The female to young ratio in a stable population of most of the mammals is approximately 2:1 (Smith 1990), whereas in this study it is 1:2.85, which represents more number of young, thus indicating a normally growing population (Smith 1990).

Group size

The mean group size of the Wild pig population in the present study (3.79) was within the range reported at other places and was very close to the most frequent group size (4) exhibited by European populations (Bon *et al.* 1986). Mean group size for Iberian populations is generally 3-5 individuals (Rosell *et al.* 2001) and a group size of 4.4, 4.3 and 3.2 individuals per group have also been reported in other populations (Merino and Carpinetti 2003; Rosell *et al.* 2004). Larger groups were detected in short grassland open area, dry wetland and mixed habitat, whereas smaller groups were seen in woodland and tall grassland savannah. Mainly two factors are known to affect the grouping behaviour of the ungulates, first to avoid predation (Hamilton 1971), and the second relates to the distribution and availability of food supply (Altman 1952). However, in the absence of predation pressure in the area, food availability seems to govern the group size of the Wild Pig population.

Habitat use

The short grassland open area was used more than was available. Food availability, shelter, thermal comfort, safety, quietness, weather conditions and human disturbance acted as significant determinants in habitat selection by Wild pigs (Kurz and Marchinton 1972; Kearney and Gilbert 1976; Singer *et al.* 1981; Meriggi and Sacchi 1992; Boitani *et al.* 1994; McCann *et al.* 2003). Deciduous woodlands generally provide the most appropriate habitat for Wild pigs (Leaper *et al.* 1999). But human intervention and disturbance affect Wild pig presence (D'Andrea *et al.* 1995; Maillard and Fournier 1995; DEFRA 2005); therefore the woodland habitat in KNP, experiencing the maximum disturbance being located near the boundary, is less preferred. Wild pigs are known to use open habitats, such as heathland and grassland. Although these offer little shelter, they do provide alternative food resources (Leaper *et al.* 1999). Wild pigs are generalist and are well-known to alter their diets according to availability (Coblentz and Baber 1987; Schley and Roper 2003; Massei *et al.* 1996). They alternatively consume plant species associated with grassy heathland habitats, for example, broad-leaved grasses and roots of certain species (Groot *et al.* 1994). Hence, these habitats are important to wild pig, though being suboptimal (Leaper *et al.* 1999). Also, this habitat exhibited the maximum Habitat Preference Index (HPI) during the entire study period. The late sightings of Wild pigs in open area on warm winter mornings and early sightings in cool pleasant summer mornings go in accordance with the fact that the animal is active when difference between body temperature and atmospheric temperature is minimum (Haque 1990). Therefore, ungulates are in open during the warmer parts of the day in winter and tolerable parts of the day during summer to escape heat (Haque 1990).

The mixed habitat was preferred next to the short grassland open area. Wild pigs are generally found to live in mixed

forest stands and meadows, and do not leave their home ranges until extensively disturbed (Polmeyer and Sodiekat 2003). High HPI for mixed habitat next to short grassland in April can be because Wild pigs, lacking sweat glands as a physiological means of thermoregulation, employ behavioural mechanisms to regulate body temperature (Coblentz and Baber 1987). The presence of dense shrub cover of *Salvadora persica* and *Capparis separia* provide cool resting places for Wild pigs. Haque (1990) also confirmed the preference of shrub layer mostly in summer and used as shelter against sun, Wild pigs being reluctant to come out during the day.

Woodland and dry wetland habitats were used in proportion to their availability. Mature woodlands are mostly preferred by Wild pigs (Leaper *et al.* 1999); wetlands provide high quality habitats for wild pig population because they provide shelter and a wide variety of food resources (Massei *et al.* 1996). But, the comparatively lower preference and least HPI values in all the months could be attributed to a high intensity of disturbance (D'Andea et al. 1995; Maillard and Fournier 1995; DEFRA 2005) and water scarcity in the wetlands due to dry conditions. The avoided habitats were tall grassland savannah and *Prosopis juliflora* thickets. Habitat use by Wild pigs is determined by food availability, shelter, weather conditions and human disturbance (Kurtz and Marchinton 1972; Meriggi and Sacchi 1992; Boitani *et al.* 1994). The available grass species in the grassland, i.e., *Viteveria zizanioides* and *Desmostachya bipinnata* being coarse, old and almost unpalatable were accompanied by low cover due to low shrub density. Therefore, these alongwith the extent of disturbance in the two habitat types might be attributed for the avoidance.

The positive correlations of Wild pig density with grass variables supports the fact that it is primarily a herbivore and depends on grass and other tuberous species (Henry and Conley 1972; Baber and Coblentz 1987; Schley and Roper 2003). Also during dry season, wild pigs are known to prefer *Cyanodon* bottoms because of their physiological need for free water and behavioural responses to high temperature (Baber and Coblentz 1986). The significant positive correlation between pellet group densities of Wild pig and Chital, Nilgai and Hare indicate a positive interaction among these species. Shared resources sometimes facilitate coexistence of different ungulate species in a community (Bagchi *et al.* 2003). Highly significant negative correlation with various tree attributes was clearly because of poor forage availability, low cover and high disturbance. Distance from water source showed highly significant negative correlation with Wild pig pellet group density, thus confirming that water source plays a vital role in the selection of a suitable habitat. The availability of water is unlikely to be a limiting factor in some areas (Leaper *et al.* 1999).

The study demonstrates a consistent growth in the wild pig population in the National Park together with the factors including food availability, shelter, human disturbance and water availability playing a major role in the habitat utilization patterns of the animal. However, the growing population also solicits for an apparent increase in the availability of the food resources. Therefore, the existing habitats, especially grasslands should be managed efficiently to avoid the human-animal conflict with the surrounding areas.

ACKNOWLEDGEMENTS

We are sincerely grateful to the Department of Wildlife Science, Aligarh Muslim University, Aligarh, for the continuous encouragement and support provided throughout the work period. We especially thank Dr. Jamal A. Khan for an excellent provision of facilities in the Department that made our work extremely smooth and comfortable. Also, we thank the officials of the Forest Department and the Government of Rajasthan for granting us permission to work in the National Park and their tremendous cooperation, help and encouragement in the field. Also, it would have been hard to carry out the study without the continued assistance of Moda and Pajji in the field.

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NOTES ON THE DISTRIBUTION, NATURAL HISTORY AND VARIATION OF *HEMIDACTYLUS ALBOFASCIATUS* (GRANDISON AND SOMAN, 1963) (SQUAMATA: GEKKONIDAE)

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Recently collected specimens of *Hemidactylus albofasciatus* from Malvan, Sindhudurg district, Maharashtra, represent a new locality record of this species and extend the species' known range southwards. Observations of these geckos provide new insights into the habitat and distribution of this uncommon species. Data from these specimens and others in the Collection of the Bombay Natural History Society (BNHS) permit the assessment of morphological variation with respect to published information about this species. In view of lack of proper taxonomic characters we take this opportunity to provide detailed description of this species.

Key words: *Hemidactylus albofasciatus*, BNHS Collection, taxonomy, natural history, new locality, habitat

INTRODUCTION

Hemidactylus albofasciatus a small, slender gecko was described by Grandison and Soman in 1963 from a series of specimens from Dorle, Dabhil and Gavakhadi villages, Ratnagiri district, Maharashtra. It has a snout vent length (SVL) of 29.6 mm, and is one of the most uncommon Indian geckos. Information on this species, except the data presented in its original description, is scarce.

Recently, this species was included in the genus *Teratolepis* (Kluge 2001; Das 2003), presumably, based on the presence of enlarged scales on the tail and narrow digital lamellae. However, a recent molecular phylogenetic analysis (cyt b, ND4, RAG-1 and PDC genes) by Bauer *et al.* (2008) reveals that *Teratolepis* is imbedded within the Tropical Asian clade of *Hemidactylus*. Apart from this, it was also evident from morphological characters that *H. albofasciatus*, with small granular scales intermixed with enlarged tubercles, is closer in dorsal pholidosis to species of *Hemidactylus* than to the other species (*T. fasciatus*, now *H. imbricatus*) previously allocated to *Teratolepis*. Variation in the degree of lamellar division is also high across *Hemidactylus*, however there is a tendency towards undivided lamellae in Indian members of the genus, culminating in *H. anamallensis* (Bauer and Russell 1995).

Recently, five specimens of *H. albofasciatus* were collected from Malvan in the Sindhudurg district of Maharashtra, and deposited in the collections of the Bombay Natural History Society (BNHS). We have also collected four specimens of this species from Dabhil-Ambere in Ratnagiri district. Apart from this, the BNHS collection also houses 7 previously collected specimens of this species, including the holotype. As information about the habitat, natural history, and morphological variation of this species is meagre, we take this opportunity to provide additional information. Apart from this, there are ambiguities regarding some unique morphological characters, like dorsal pholidosis, digit morphology and coloration, which play a vital role in taxonomy. We redescribe the species in greater detail to avoid further taxonomic confusion.

MATERIAL AND METHODS

The specimens of *H. albofasciatus*, BNHS 1841-1842, BNHS 1852-1853, BNHS 1867 and BNHS 1952 from Malvan, Sindhudurg district, and BNHS 1579-1582 from Dabhil-Ambere, Ratnagiri district, Maharashtra, were collected, fixed in 10% formalin, and transferred into 70% ethanol. Mensural and meristic features of these specimens are reported in Table 1. Measurements taken with a Dial Caliper (to the nearest 0.05 mm) were: snout-vent length (SVL; from tip of snout to vent), trunk length (TRL; distance from axilla to groin measured from posterior edge of forelimb insertion to anterior edge of hindlimb insertion), body width (BW; maximum width of body), crus length (CL; from base of heel to knee); tail length (TL; from vent to tip of tail), tail width (TW; measured at widest point of tail); head length (HL; distance between retroarticular process of jaw and snout-tip), head width (HW; maximum width of head), head height (HH; maximum height of head, from occiput to underside of jaws), forearm length (FL; from base of palm to elbow); orbital diameter (OD; greatest diameter of orbit), nares to

Fig. 1: Dorsal view of the mid-body of *Hemidactylus albofasciatus*, (BNHS 1852). Note the dorsal pholidosis

eye distance (NE; distance between anterior-most point of eye and nostril), snout to eye distance (SE; distance between anterior-most point of eye and tip of snout), eye to ear distance (EE; distance from anterior edge of ear opening to posterior corner of eye), interorbital distance (IO; shortest distance between left and right supraciliary scale rows).

Meristic data recorded for all specimens were number of supralabial scales (SL), infralabial scales (IL), precloacal pores (PCP), and lamellae under digits of manus (MLam) and pes (PLam) for both left (L) and right (R) sides. Scale counts and external observations of morphology were made using a Wild M5 dissecting microscope.

RESULTS

Variation in morphological characters

Though the original description of *H. albofasciatus* was based on 30 specimens, morphological characters, like dorsal pholidosis, digit morphology, and coloration, which play fundamental role in taxonomy, were imprecisely described by Grandison and Soman (1963).

The maximum length of *H. albofasciatus* was reported by Grandison and Soman (1963) as 29.6 mm SVL, with tail length as much as 26.5 mm. Several of our specimens exceed this, and one specimen (BNHS 1580) is of an appreciably larger size of 34.8 mm SVL and 35.70 mm TL (Table 1).

Grandison and Soman (1963) described the dorsum as 'back with small, keeled granules, intermixed with larger trihedral tubercles, which are twice as large as the granules. About 80 mid-body scales. Tubercles arranged irregularly, separated by one to three granular scales.' As per our observation, dorsal scales are heterogeneous, small, conical, keeled, and striated; intermixed with irregularly arranged, enlarged, conical, strongly keeled and striated tubercles, which are roughly twice the size of adjacent scales (Fig. 1).

The tail of *H. albofasciatus* was described by Grandison

Table 1: Mensural data for the specimens of *Hemidactylus albofasciatus*

BNHS No.	148	1247	1248	1249	1250	1251	1579	1580	1581	1582	1841	1842	1852	1853	1867	1952
SVL	29.8	34.3	30.3	29.1	30.0	28.7	29.3	34.8	30.7	30.3	33.7	26.0	31.2	30.8	27.2	29.5
TRL	14.2	15.5	12.5	12.0	12.4	11.0	13.0	15.9	13.1	12.7	16.0	11.3	14.8	14.2	13.2	12.9
BW	4.8	5.9	4.8	5.2	4.7	4.7	5.1	6.7	5.1	6.0	4.5	3.5	6.8	6.6	5.2	5.7
CL	4.9	4.8	4.8	4.9	4.8	4.3	5.1	5.5	5.0	4.9	5.0	4.2	4.5	4.7	4.5	4.7
TL	27.5	-	31.2	21.60*	-	19.10*	20.1*	35.7	18.3*	29.7	21.0*	28.7	29.1	9.10*	28.1	11.5*
TW	2.9	-	3.5	3.2	-	3.1	3.7	4.9	3.1	3.4	3.0	2.3	3.6	3.3	3.0	3.3
HL	9.0	10.2	9.5	9.1	9.2	9.2	9.5	10.5	9.3	9.2	10.7	8.3	9.6	10.0	8.9	10.0
HW	5.4	6.4	5.8	5.9	5.4	5.5	6.0	6.9	6.0	6.0	6.2	4.7	6.0	6.6	4.8	6.3
HH	3.9	4.1	4.0	3.8	3.8	3.5	3.9	4.2	3.8	3.8	4.0	3.1	3.4	3.8	3.2	4.0
FL	4.4	4.6	4.2	4.5	4.1	4.2	4.5	4.7	4.2	4.3	4.8	3.6	4.4	4.6	4.1	4.1
OD	2.3	2.1	2.1	2.1	2.1	2.1	2.0	2.2	1.9	2.0	2.2	1.6	2.2	2.2	1.9	2.0
NE	2.8	2.6	2.3	2.4	2.5	2.3	2.5	2.6	2.5	2.6	2.9	2.4	2.7	2.6	2.4	2.4
SE	3.7	4.0	3.6	3.7	4.0	3.9	3.4	4.0	3.2	3.4	3.7	3.0	3.3	3.6	3.1	3.6
EE	2.7	3.5	2.9	2.9	3.1	3.0	2.5	3.3	2.9	2.8	3.1	2.5	2.6	2.7	2.1	2.9
IO	2.5	2.5	2.5	2.4	2.3	2.5	3.1	3.1	2.2	2.4	3.3	2.5	2.7	3.0	2.5	3.1

Abbreviations as in Materials and Methods section; all measurements in mm.
Asterisk refers to damaged/missing tail.

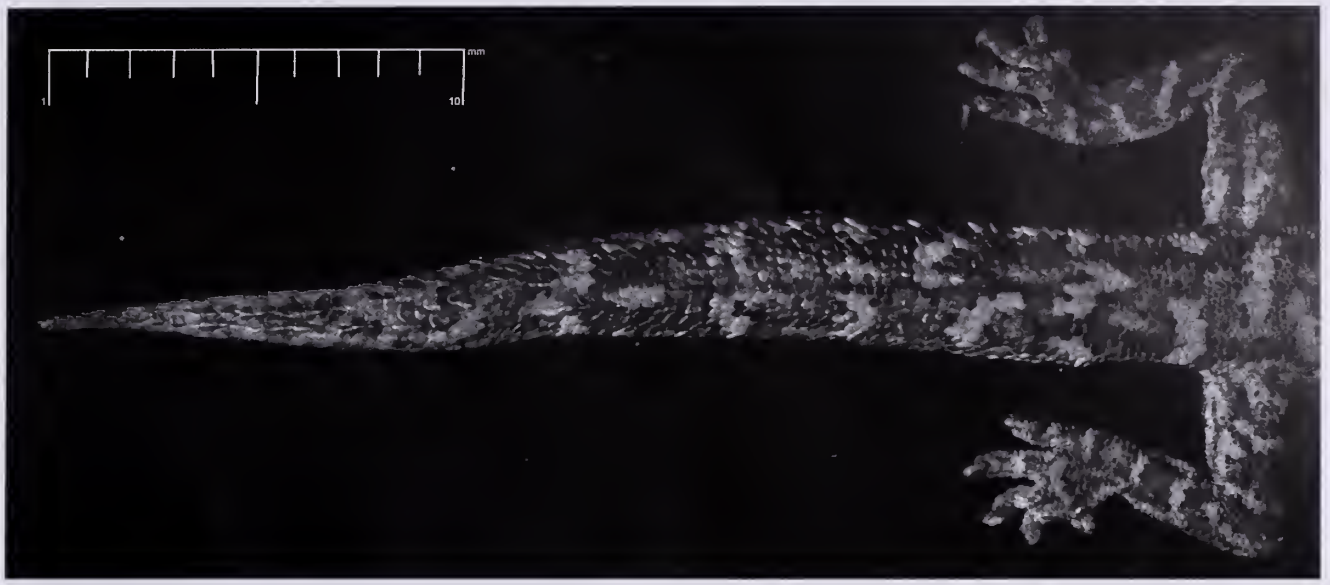

Fig. 2: Dorsal view of tail of *Hemidactylus albofasciatus* (BNHS 1852). Note the smaller size of scales

and Soman (1963) as 'round in section, tapering, verticillate covered above with faintly keeled, pointed, imbricate scales; in the middle of each whorl and to either side of the vertebral line are two longitudinal rows of larger, pointed, keeled scales.' As per our observation on fresh specimens in the BNHS collection, the tail is covered above with large, flat, weakly pointed, strongly imbricate and striated scales with a series of two to four rows of much larger, flat, strongly pointed, keeled and striated scales on either side of median furrow (Fig. 2).

Apart from the shape and size of the body, toe morphology is also an indicator of habit among species of *Hemidactylus* (Bauer *et al.* 2008; Giri *et al.* 2008). Grandison and Soman (1963) mentioned: 'digits free, with little dilation; distal joints rather short'. According to us digits are short, clawed; terminal phalanx of all digits curved, arising angularly from distal portion of expanded lamellar pad, less than half as long as associated pad. They described lamellae as 'in a straight transverse series; undivided except for the penultimate and two or three more proximal plates, which are notched; eight or nine, exceptionally ten lamellar plates under the fourth toe, five under the first toe'. Our observations of material from the BNHS collection confirm these ranges except that the lamellae are in oblique series, there are four to six lamellae under the first toe and three to five proximal lamellae under

Table 2: Meristic data for the specimens of *Hemidactylus albofasciatus*

BNHS No.	MLam L	MLam R	PLam L	PLam R
148	5(1)-6(3)-7(3)-7(3)-7(3)	5(1)-6(2)-7(3)-7(3)-7(3)	5(1)-6(3)-8(3)-8(3)-8(4)	5(1)-6(2)-8(3)-9(3)-8(4)
1247	5(1)-6(3)-7(3)-7(3)-7(3)	5(1)-6(3)-7(3)-7(3)-8(3)	0-7(3)-8(3)-9(4)-8(2)	5(1)-7(4)-7(3)-10(4)-8(3)
1248	0-6(3)-6(3)-7(3)-7(3)	0-6(3)-7(3)-7(3)-8(3)	0-7(3)-8(3)-9(4)-8(2)	5(1)-7(4)-7(3)-10(4)-8(3)
1249	5(1)-6(2)-6(2)-7(3)-7(3)	5(1)-0-0-7(3)-7(3)	5(1)-6(2)-7(3)-9(4)-8(3)	5(1)-6(2)-7(3)-9(3)-6(2)
1250	5(1)-6(2)-7(3)-7(3)-7(3)	0-0-0-0-0	5(1)-6(2)-7(3)-7(3)-7(3)	5(1)-7(3)-8(3)-9(3)-6(3)
1251	5(2)-6(3)-6(3)-7(4)-7(3)	5(1)-6(3)-0-7(4)-6(3)	5(1)-7(3)-7(3)-9(4)-8(3)	5(2)-0- 8(3)-9(4)-7(3)
1579	5(2)-7(4)-7(4)-7(4)-6(3)	5(2)-7(3)-7(4)-7(4)-7(3)	5(2)-7(3)-8(4)-10(4)-8(4)	5(2)-7(3)-8(4)-10(5)-8(4)
1580	5(1)-6(3)-7(3)-7(3)-7(3)	5(1)-6(3)-0-7(3)-7(3)	6(2)-6(4)-8(4)-9(4)-8(3)	6(2)-6(4)-8(4)-9(4)-8(4)
1581	6(1)-6(3)-7(3)-7(3)-7(3)	5(1)-6(3)-7(3)-7(3)-7(2)	6(1)-7(3)-8(3)-9(4)-8(3)	6(1)-7(3)-8(3)-10(4)-8(3)
1582	5(1)-6(2)-6(3)-7(3)-7(3)	5(1)-6(2)-6(2)-7(2)-7(2)	5(1)-7(3)-8(3)-8(3)-8(3)	5(1)-7(2)-8(2)-9(3)-8(3)
1841	5(1)-6(2)-7(3)-7(3)-7(3)	5(1)-6(2)-6(3)-7(3)-7(3)	5(1)-6(3)-7(3)-10(4)-8(3)	5(2)-6(3)-7(3)-10(4)-8(3)
1842	5(1)-6(2)-7(3)-7(3)-7(2)	5(2)-6(2)-7(2)-7(2)-7(2)	5(1)-6(2)-7(3)-9(4)-7(3)	5(1)-6(2)-7(3)-9(4)-7(2)
1852	5(1)-6(3)-7(3)-7(3)-7(3)	5(1)-6(3)-7(3)-7(4)-7(3)	4(1)-7(4)-8(4)-9(5)-8(4)	4(1)-6(3)-8(4)-9(5)-9(4)
1853	5(1)-6(2)-7(3)-7(3)-7(3)	5(1)-6(2)-7(3)-7(3)-7(3)	4(1)-7(3)-8(3)-9(3)-8(3)	4(1)-6(3)-8(4)-9(4)-9(3)
1867	5(1)-6(3)-6(3)-7(3)-6(2)	5(1)-6(2)-6(3)-7(3)-6(3)	4(1)-6(3)-7(4)-8(4)-0	5(1)-6(3)-7(4)-9(4)-8(3)
1952	5(1)-6(3)-7(3)-7(3)-7(3)	5(1)-6(3)-7(3)-7(3)-7(3)	5(1)-7(3)-7(4)-9(4)-8(3)	5(1)-6(3)-0-9(5)-8(3)

Values in parenthesis represent the number of notched lamellae.
'0' indicates damaged lamellae

the fourth toe which are notched (Fig. 3) (Table 2).

We did not observe any variation in the number of precloacal pores. There are 7-8 precloacal pores in the seven males studied by us.

Grandison and Soman (1963) described the coloration of *H. albofasciatus* as 'ground colour dark brown; a whitish streak, two scales wide, runs from the nostril through the eye to above the ear. Ten narrow, somewhat wavy, whitish bands run transversely from behind the eyes to the hind limbs; interspaces three times the width of a band. Tail similarly cross-banded at each alternate whorl. Ventral surfaces cream with fine brown speckling. A longitudinal, mid-ventral dark line is present on the tail.' Though the coloration was described in the original description, we observed some variation in our material.

Detailed description

Thus, in view of the above mentioned variations and to discuss morphological characters in detail we provide herewith a detailed description based on recently collected material and specimens in the Collection of the BNHS (BNHS 1247-1251), including the holotype (BNHS 148).

Body slender, SVL 26.0-34.8 mm. Head short (HL/SVL = 0.3-0.33), slightly elongate (HW/HL = 0.54-0.66), not strongly depressed (HH/HL ratio 0.35-0.43), distinct from neck. Loreal region not inflated, canthus rostralis not prominent. Snout short (SE/HL = 0.34-0.43); slightly longer than twice as long as eye diameter (OD/SE = 0.53-0.67); scales on snout and canthus rostralis juxtaposed, smooth, weakly conical, slightly larger in size than those on forehead; occipital and interorbital region with much smaller, conical granular scales. Eye small (OD/HL = 0.19-0.26); pupil vertical with crenulated margins; supraciliaries small, pointed, those at the anterior end of orbit slightly larger. Ear opening very small, oval and oblique; eye to ear distance slightly greater than diameter of eye (EE/OD = 1.11-1.67). Rostral wider than deep, slightly notched, divided mid-dorsally by weakly developed rostral groove; one enlarged internasal separated by one or two small scales, two postnasals, of which posterior is larger; rostral in contact with first supralabial, supranasals, and a single internasal; nostrils circular, each surrounded by supranasal, rostral, first supralabial, and two subequal postnasals; 2-3 rows of scales separate orbit from supralabials. Mental triangular; two pairs of postmentals, inner pair single, larger and in contact behind mental, outer postmental is medially divided; inner postmental is bordered by mental infralabial 1, posterior postmentals and two chin scales; outer postmental is bordered by inner postmental, infralabial 2, and three to four enlarged chin scales. Infralabials bordered by single row of enlarged scales that grade into granules medially

Fig. 3: Ventral view of the lamellae of right pes of *Hemidactylus albofasciatus* (BNHS 1852). Note notched lamellae

and posteriorly. Supralabials to mid-orbital position 6, to angle of jaw 7-9; infralabials to angle of jaw 7. Body relatively elongate (TRL/SVL = 0.38-0.49). Ventrolateral skin folds inconspicuous, without denticulate edges. Dorsal scales heterogeneous, small, conical, keeled, and striated; intermixed with irregularly arranged, slightly enlarged, conical, strongly keeled and striated tubercles, extending from neck to tail; each enlarged tubercle roughly twice the size of adjacent scale and surrounded by rosette of 8-9 small scales, 2-4 scales between adjacent enlarged tubercles. Ventral scales larger than dorsal, smooth, imbricate, slightly larger on abdomen and precloacal region than on chest (Fig. 5, Ventral, full body); midbody scale rows across venter to lowest row of tubercles 28-30; gular region with smallest and rounded granules, anterior gular scales are much larger than the rest. Scales on palms and soles smooth, rounded; scales on dorsal aspect of forelimb flat, larger than those on body dorsum, imbricate and strongly striated; dorsal scales on thigh larger, flattened and striated, those on the back of the thigh are smaller, conical, keeled and striated. Fore- and hind limbs relatively short, thin; forearm short (FL/SVL ratio 0.13-0.150.14); tibia short

Fig. 4: Live *Hemidactylus albofasciatus* (specimen not collected). Note the coloration

(CL/SVL ratio 0.14-0.170.14); digits moderately short, strongly clawed; all digits of manus and digits I-IV of pes indistinctly webbed; terminal phalanx of all digits curved, arising angularly from distal portion of expanded lamellar pad, less than half as long as associated pad; scansors beneath each toe undivided, the plate adjacent to terminal scansor is, however, deeply notched and the two or three next proximal plates are less strongly so; scansors (from proximal-most at least twice diameter of palmar scales to distal-most single scansor, number of notched lamellae in parentheses): 5(1)-6(2/3)-6/7(2/3)-7(3/4)-6/8(2/3) (right manus), 4/6(1/2)-6/7(2/4)-7/8(3/4)-9/10(3/5)-6/9(2/4) (right pes). Tail cylindrical, tapering to a fine point, with a median furrow, oval in section, flat beneath; length of original, entire tail is more or less equal to snout-vent length (TL/SVL ratio 0.92-1.10 (n=7)); tail covered above with large (much larger than those on the dorsum), flat, weakly pointed, strongly imbricate and striated scales with a series of two to four rows of much larger, flat, strongly pointed, keeled and striated scales on either side of median furrow; ventral scales much larger than above, smooth, pointed and strongly imbricate; 2 enlarged postcaudal spurs on either side of tail base.

Back with three pronounced, brown, longitudinal stripes, one vertebral and two paravertebral, running from occiput to tail. These stripes are interrupted by a series of six thin, white, transverse, irregular/broken bands which are bordered with brown, one each on shoulder and sacrum and rest on dorsum. A paravertebral series of five, paired, creamish-white somewhat oval blotches between the transverse bands and longitudinal stripes. Two lateral, broken, creamish-white stripes present on the flank on each side. Of which the dorsal stripe starts from near the shoulder, reaches to tail base and in contact with transverse streaks. The ventral stripe runs from back of the jaw to the base of the tail. (Fig. 4)

Upper surface of head dark brown with alternately arranged creamish-white transverse streaks. A whitish streak running from the rostral, passing through orbit and above ear, which connects with transverse band on shoulder on both the sides, in some this band is entire and in a few it is broken. Rostral and anterior one or two supralabials dark brown; upper half of subsequent one or two supralabials brown, remaining supralabials whitish. Lower half of infralabials brownish and remaining portion whitish. There are small brownish dots visible in the whitish portion of both, supralabials and infralabials. Anterior supralabials creamish-white mottled with dark brown, which gives them a brownish appearance. Posterior supralabials creamish-white again mottled, with grayish brown. Forelimbs and hindlimbs brown with irregular, narrow white bands above and below elbows continuing on hands/feet and digits. Original portion of the tail dark brown with six creamish-white, broken, thick transverse bands. A whitish, unbroken, lateral streak running from base of the tail to the tip is present on both the sides. The regenerated tail portion is mottled with dark brown and white. In juveniles the tail is sometimes bright orange ventrally. Body venter creamish-white, semi-translucent, with brownish markings on the lateral aspect of the abdomen. Tail venter with a series of three narrow, dark brown stripes, mid-ventral is entire, thin and bold, lateral pair thicker but appear broken. In preservative, coloration is similar to that in life, except ventral stripes on belly and tail, which are inconspicuous.

Distribution

Hemidactylus albofasciatus is one of the most poorly known geckos in India. This species has previously been recorded only from a few localities in Ratnagiri district, Maharashtra (Grandison and Soman 1963; Tikader and Sharma 1992). Recently collected specimens of *H. albofasciatus* from Malvan, Sindhudurg district, Maharashtra (16° 1' 52.10" N; 73° 31' 48.73" E) represent a new locality record of this species. This locality is about 100 km south of the presently known localities of this species. We have also recorded this species from Kunakeshwar (16° 20' 03.23" N; 73° 23' 29.83" E) in the Sindhudurg district.

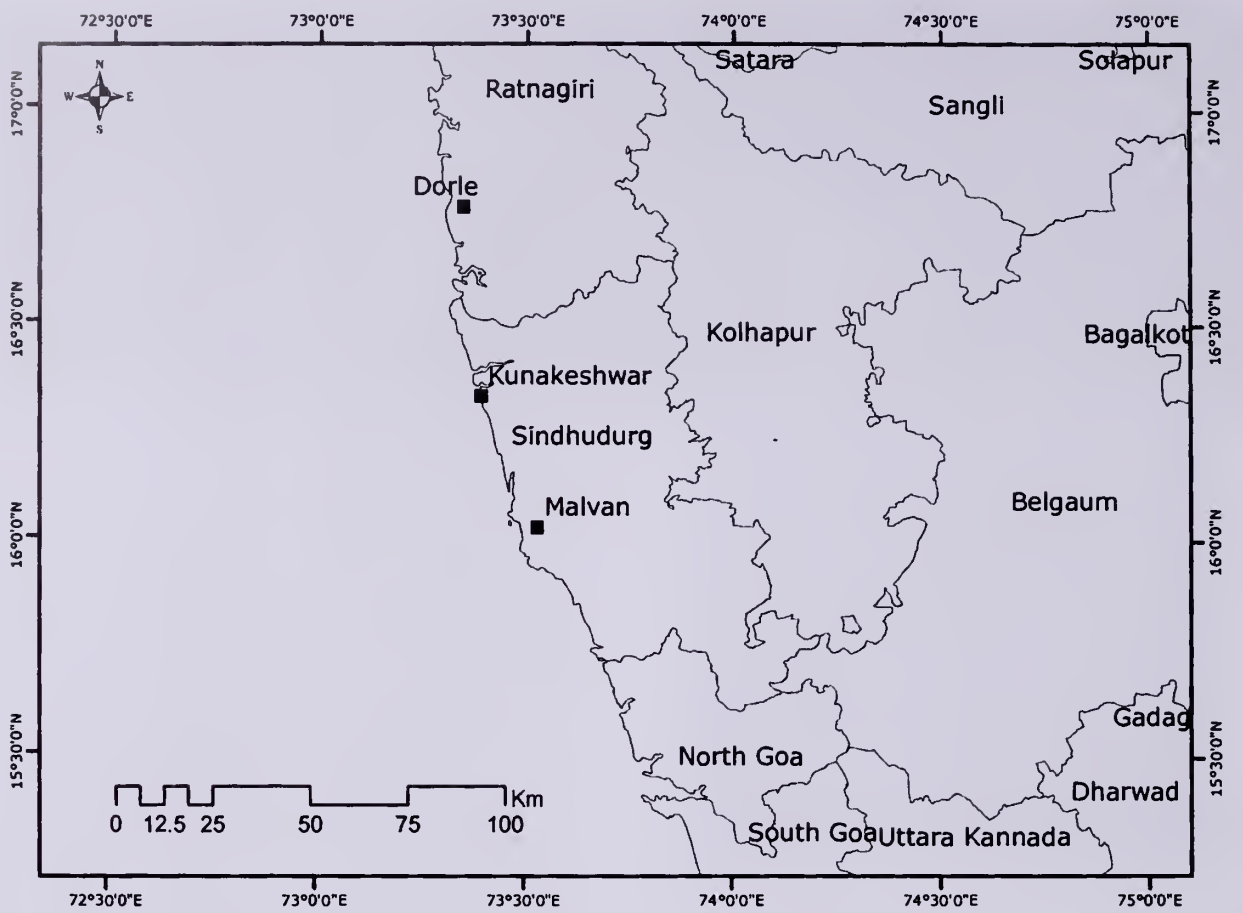

Fig. 5: Map showing different localities of *Hemidactylus albofasciatus*

This locality is roughly in between the type locality and Malvan. We have also reported this species from one of the type localities, Dorle (16° 46.35' N; 73° 20.8' E) in Ratnagiri district during our survey (Fig. 5).

Locality and habitat

The only information about the habitat for this species was provided by Grandison and Soman (1963) as 'open, rocky crests of hills bearing few patches of scrub mainly *Carissa carandas* and *Holarrhena antidysentrica*, the surrounding country is jungle of semi-evergreen nature.'

Fig. 6: Habitat of *Hemidactylus albofasciatus* at Malvan, district Sindhudurg, Maharashtra

The recently collected specimens of *H. albofasciatus* from different plateaux near Malvan, Sindhudurg district, Maharashtra, are also from a similar habitat. This locality is barely 50 m above sea level. The habitat is similar to the type locality and other localities in Ratnagiri district from which this species has previously been reported (Fig. 6).

The coastal tract of Maharashtra and Goa, locally called '*Konkan*', is one of the major geographic divisions of western India. The geomorphology of Konkan is characterized by a coastal plain of variable altitude and width, backed by the escarpment of the Western Ghats on the east and the Arabian Sea, with or without a cliff, on the west. It covers a north south distance of about 720 km, with an average width of 60 km.

Another unique feature of the Konkan coast is the presence of plateaux, locally called '*sada*'. These plateaux are mostly present on the crest of small hills or mountains, generally at lower altitudes, on the coastal belt between the Arabian Sea and Western Ghats. Although the habitat is degraded due to anthropogenic pressure, there are comparatively less disturbed patches of semi-evergreen forest

in the valleys in some localities. These are mainly lateritic plateaux that appear barren due to sparse vegetation, except during the monsoon when they are mostly covered with grass and a variety of monsoon flora. The herpetofaunal diversity is mainly composed of *Ophisops* sp., *Lygosoma guentheri*, *Echis carinata*. Apart from this, an endemic species of caecilian *Gegeneophis seshachari* is also known from these plateaux.

Natural History

These plateaux were visited by us in different seasons from 2003 to 2008. We observed that *H. albofasciatus* mostly hide under rocks during the day. Though we never observed any eggs, the juveniles are mostly seen in June to August. The ventral part of the tail of juveniles is bright orange. We also observed variation in the thickness of tails; a few geckos had fat tail, while others were slender. The adults mostly remain motionless when the rock above them is turned. The typical behaviour of ground dwelling species, raising the fore-body and neck is also observed in this species. The juveniles are comparatively active and escape at a slight disturbance. It appears to be a poor climber; unlike its congener *Hemidactylus* cf. *brookii*, which can climb on or adhere to the rocks it uses for retreat sites. This species appears solitary as we rarely observed more than one gecko under a rock. Nonetheless, it is one of the commonest species of lizards on certain plateaux visited by us. On every plateau, though the habitat appears uniform, the geckos are unevenly distributed. Our team of five observed 16 individuals of this species in 25 minutes of active search on one of the plateaux near Malvan in July 2007. Of these, seven individuals were juveniles. All these individuals were concentrated on a small portion (approx. 100 m x 100 m) of this plateau. An intensive search for a longer duration on other parts of the same plateau at the same time yielded only two geckos. We also spotted 20 adult *H. albofasciatus* in approximately 20 minutes on a plateau near Dabhil-Ambere in the Ratnagiri district in October 2003. Here also they were concentrated in a small portion of the available habitat. One of the authors (HK) spotted three adults and one juvenile on a plateau near Kunakeshwar in Ratnagiri district.

This species is found sympatrically with *Hemidactylus* cf. *brookii*, *Ophisops* sp., *Lygosoma guentheri*, *Echis carinata* and an endemic amphibian, *Gegeneophis seshachari*, in most of the localities visited by us.

CONCLUSION

Our observations on morphological characters confirm that this gecko belongs to a largely terrestrial subgroup of genus *Hemidactylus* that has recently been identified as a distinct clade (Bauer *et al.* 2008). There have been several new additions to Indian *Hemidactylus* in recent years (Giri and Bauer 2008; Giri 2008; Giri *et al.* 2009; Mahony 2009). This necessitates a proper taxonomic study of the earlier described species of Indian *Hemidactylus*. Ambiguities in taxonomic characters may lead to wrong identification. The redescription provided here may mitigate taxonomic problems related to ground dwelling species of Indian *Hemidactylus*.

Hemidactylus albofasciatus is considered as one of the most poorly known geckos, but they are commonly seen in the area of their occurrence. The typical body form and toe morphology are consistent with its ground-dwelling habits. Apart from this, *H. albofasciatus* is a habitat specific gecko and is mainly known to occur on the plateaux along the coastal belt in Maharashtra. Though this species is presently known from a few localities, in view of their habitat preference and availability of likely habitat, mostly in the Ratnagiri and Malvan districts, it is likely that they occur even further towards the north and/or south. These plateaux appear barren, but have unique faunal diversity which is mainly comprised of representatives of drier habitats. Interestingly, no efforts have been made to document this diversity in greater detail, and thus these plateaux remain one of the least studied habitats in India.

As per our preliminary observations, *H. albofasciatus* appears to be unevenly distributed, thus studies related to their microhabitat preference are essential for their conservation. Though these plateaux are undisturbed, some anthropogenic activities like grazing and collection of rocks for building compound walls were observed at certain places. Further studies related to their natural history and population need to be undertaken.

ACKNOWLEDGEMENTS

We are grateful to Dr. Aaron M. Bauer for his valuable comments and suggestions while preparing this draft. We are thankful to Dr. Asad R. Rahmani and Mr. J.C. Daniel for the opportunity to carry out this study. We are also thankful to Sameer Kehimkar, Ishan Agarwal, Swapnil Pawar, Sandeep Sohoni, Rohan Korgaonkar, Kunal Mayekar and Rajat Toroskar for their assistance in the fieldwork. Thanks to Vithoba Hegde and Shyam Jadhav for their curatorial assistance. Thanks to Mohit Kalra for preparing the distribution map. The trip to Dorle was possible due to Dr. Mark Wilkinson and Dr. David Gower of The Natural History Museum, London. We are thankful to the Declining Amphibian Task Force and Ruffords Small Grants for their generous grants to carry out field visits. Thanks to Mr. Uday Korgaonkar for his hospitality during our stay at Dorle village. KG is thankful to Kshitij Gaikwad and Kedar Bhide.

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FISH FAUNA OF THE WETLANDS OF SRIHARIKOTA ISLAND, SOUTHERN INDIA AND THEIR CONSERVATION ISSUES

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Fish fauna in different wetlands of Sriharikota Island was assessed during February 2002 to April 2004. A total of 53 fish species belonging to 36 families and 10 orders were recorded. Nineteen species were recorded from freshwater habitats, 38 from fresh-brackish and 39 from brackish-saline wetlands. Two important perennial wetlands in the Island, Malliplate Vagu (a fresh-brackish stream) and Urugayya (a brackish-saline lake), also serve as nurseries for young of marine fish and prawn species, including two Anguillid eels. The abandoned irrigation ponds are major refuges for two threatened air-breathing species, *Clarias batrachus* and *Anabas testudineus*. An exotic species *Oreochromis mossambicus* and a species native to north India *Colisa lalia*, were also recorded. The species composition and relative abundance of fish species in the major wetlands are discussed individually. Problems facing the wetlands are siltation and invasion by the introduced cane species *Calamus rotang*. The invasive aquatic weed *Eichhornia crassipes* is also a major problem in abandoned irrigation ponds. Sriharikota due to its high security status and largely undisturbed and unpolluted habitats has the potential to be a future conservation site for the fish fauna of this region – if the *status quo* remains.

Keywords: fish fauna, Sriharikota, wetlands, conservation

INTRODUCTION

India's burgeoning human population and its largely rural makeup places huge demands on natural resources including wetlands leading to their exploitation, alteration and degradation. It is estimated that around 50,000 small and large wetlands in India are polluted to the point of being dead (Lee Foote *et al.* 1996). Thus, it is important that even areas having small, unspoiled aquatic habitats be documented and afforded protection as these could in future be important refuges for fish fauna of the regions they represent.

As part of the initiatives of the Satish Dhawan Space Centre (SDSC) to document the biodiversity of Sriharikota Island (in Andhra Pradesh and Tamil Nadu), the Bombay Natural History Society carried out an assessment of its fish fauna (Manakadan and Sivakumar 2004a). Till this study, the ichthyofauna of Sriharikota Island, which has a rich diversity of wetlands, was undocumented probably due to the high-security status of the island as a spaceport. This is in contrast to the fish fauna of Pulicat Lake (which borders the island on three sides) that has been extensively studied (Chacko *et al.* 1953; Krishnamurthy 1969; Prasadam 1971; Kaliyamurthy and Janardhana Rao 1972; Prabhakara Rao 1970, 1971; Kaliyamurthy 1972, 1981; Sanjeeva Raj *et al.* 1977; Raman *et al.* 1977; Sultana *et al.* 1980; Vasanth *et al.* 1990; Rema Devi *et al.* 2004). The fish fauna of Sriharikota, namely the freshwater forms, is of additional interest as these occur in an island ecosystem. This paper, an offshoot of the larger study, gives an account of the fish fauna occurring in the different wetland habitats of the Sriharikota Island and discusses the conservation issues facing these wetlands.

STUDY AREA

Sriharikota is a spindle-shaped island (*c.* 181 sq. km) situated in Nellore and Tiruvallur districts of Andhra Pradesh and Tamil Nadu respectively (Fig. 1). Besides being the satellite launching station of the Indian Space Research Organisation (ISRO), Sriharikota has one of the last remaining, largest and best-preserved tracts of coastal Tropical Dry Evergreen Forest in India. The Island is bordered to the east by the Bay of Bengal and on the west, north and south by the Pulicat Lake. The Buckingham Canal, a largely disused navigation canal of the British Era, runs along the western edge of the Island. The Island has a coastline of *c.* 56 km from north to south and its east to west dimensions vary from *c.* 9.6 km in the central part to 1 km in the southern part. The Island comprises of low ridges of sand of marine and aeolian origin, rising *c.* 4.5-6.0 m above msl and sloping from west to east. The water table is at a depth of *c.* 2 to 5 m. The rainfall is mainly from the North-east Monsoon and to a lesser degree, the South-west Monsoon, averaging *c.* 1,200 mm annually. The area is particularly prone to cyclones, usually in the early part of May and October, prior or during the onset of the two monsoons. December to February

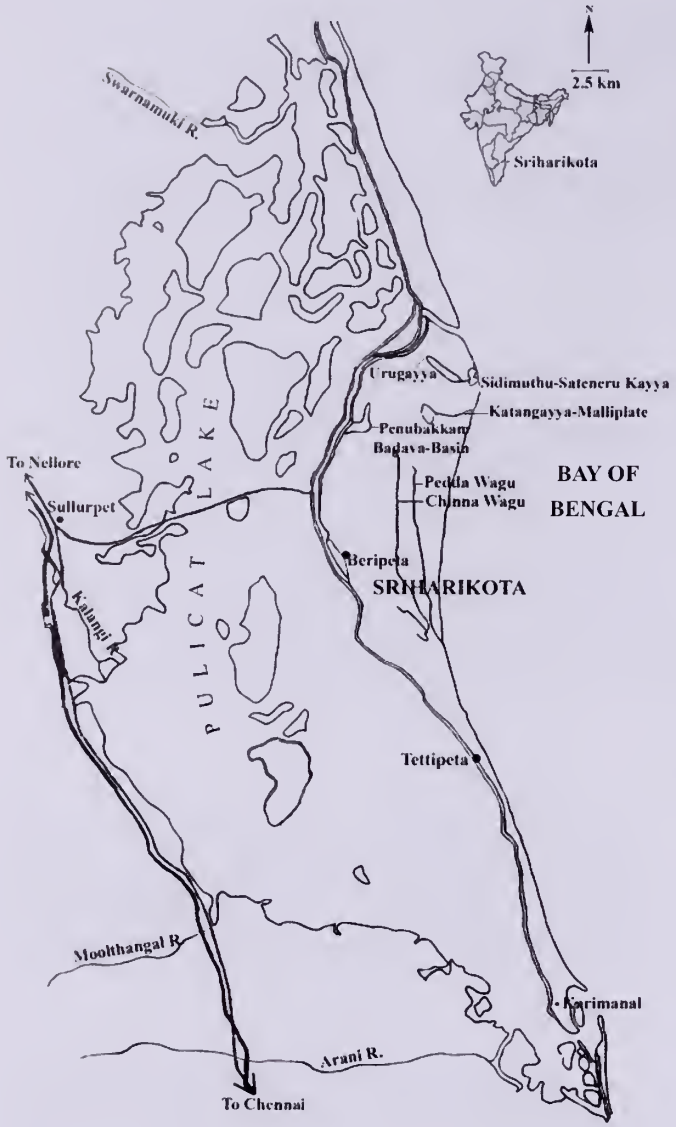

Fig. 1: Sriharikota Island and its wetlands

is the winter season with temperatures as low as 10°C, and March to September is the summer season with temperatures soaring over 40°C. Relative humidity is lowest during May (18%), and is maximum during October (99%).

METHODS

Fish sampling in Sriharikota Island was difficult due to the occurrence of a wide variety of wetlands with varying depths, turbidity, currents, presence of aquatic vegetation, debris and silt, and total or partial drying of some wetlands during summer. This was further compounded by significant microhabitat variations within habitat types. Hence, we used different sampling methods such as bank-side count, hook and line, cast-net and gill-net (Sutherland 1997; Thompson *et al.* 1998). Other methods employed to assess the ichthyofauna and to reduce the chances of missing species for making species inventories of the different wetlands were examination of fishers' catches, interviews with fishers, recording of data during emptying of drying pools by local fishers, and visual observations over clear waters – termed as 'General Collections' in Tables 3-9.

Sampling was not carried out in two (namely, Madugu Doruvu and Madugu Vagu) of the ten major wetlands of the Island (Table 1) due to extremely difficult approach and sampling related problems, and only collections for the inventory of species were made in these two wetlands. Sampling was carried out between 0730 to 1030 hrs from February 2002 to January 2003, but collection trips, incidental sampling or observations and examination of fishermen's catches continued till April 2004. Sampling was spread out over a year to cover seasonal hydrological changes, such as water levels, salinity, drying.

Taxonomy and species names in this paper follow Talwar and Jhingran (1991) and Jayaram (1999) for freshwater and brackish water species, and Talwar and Kacker (1984) for marine species with incorporation of changes since then following Nelson (2006).

RESULTS

A total of 44 fish species were recorded in Sriharikota Island (Table 2). Additionally, fishermen reported that nine more species (denoted by # in Table 2) that occur in Pulicat lake or in wetlands on the mainland around Sullurpet or/and some islands in Pulicat lake, also occur in Sriharikota. The fish fauna of different aquatic habitats in Sriharikota Island assessed during the present study are detailed below:

Pedda and Chinna vagus: Fifteen species were recorded from the two major freshwater streams, the Pedda and Chinna vagus, consisting of 7 freshwater, 3 brackish/brackish-tolerant (*Oryzias carnaticus*, *Aplocheilus parvus* and *Oreochromis mossambicus*) and 1 fresh-brackish-marine (*Megalops cyprinoides*) species (Table 3). As sampling in the vagus was difficult due to the presence of dense aquatic vegetation, there were high possibilities of missing species. It was only during the final drying stages after the dense vegetation was removed by fishers that effective sampling was possible. However, by this time, most of the fish, especially the slower and more easily caught species, were already depleted by fishers and fish-eating birds. *Mystus vittatus*, *Colisa lalia* and *Clarias batrachus* were recorded only once in a drying pool.

Abandoned Irrigation Ponds: Twelve species were recorded in abandoned irrigation ponds (Table 4). Species such as *Anabas testudineus*, *Clarias batrachus* and *Channa* spp. were dominant in irrigation ponds. The surface

Table 1: Major wetlands of Sriharikota

Name of the wetland	Habitat Type	Approximate size/length and Maximum Depth	Aquatic Vegetation	Remarks
Pedda Vagu	Freshwater Stream	15 km; 180 cm	Dense, mostly submerged macrophytes	Seasonal, flows into the Bay of Bengal during the NE Monsoon season. Perennial at the 2 km end, which is seasonally brackish and lacks aquatic vegetation, except for reeds
Chinna Vagu	Freshwater Stream	9 km; 120 cm	Dense, mostly submerged macrophytes	Seasonal. Has no opening into the sea,but gets connected to Pedda Vagu during the peak monsoon
Abandoned Irrigation Ponds	Freshwater Pond	< 1 ha each; 150 cm	Water hyacinth *Eichornia crassipes.*	Perennial/Seasonal. Most of the ponds are now heavily silted and overgrown with cane *Calamus rotang*
Madugu Vagu	Freshwater Stream	3 km; 100 cm	Dense, mostly submerged macrophytes	Seasonal. Situated *c.* 2 km north of Urugayya, the Madugu Vagu, like the Urugayya, flows into the Sateneru-Sidimuthu Kayya during the NE Monsoon season
Madugu Doruvu	Freshwater Pond	*c.* 50 ha; 100 cm	Dense, mostly submerged macrophytes	Perennial. Situated *c.* 2 km south-west of Urugayya, it flows into the Sateneru-Sidimuthu Kayya during the peak monsoon season
Malliplate Vagu	Brackish water-freshwater stream	4-5 km; 180 cm	Largely absent. Upper reaches and Katangayya, have profusion of reed beds.	Comprises of a 1 sq. km headwater, the Katangayya, and the Malliplate stream; flows into the Bay of Bengal. Largely silt laden with leaf litter and debris. Perennial except for Katangayya, which dries up in summer
Penubakkam Baadava	Freshwater Pond	*c.* 50 ha; 100 cm	Dense, mostly submerged macrophytes	Seasonal. The P. Baadava is contiguous with the P. Basin during the peak monsoon. Dries up in summer
Penubakkam Basin	Creek with inlet/outlet into Pulicat Lake	*c.* 50 ha; 120 cm	Algal mats	Seasonal. Forms the lower reaches of P. Badava, from which it receives water during the NE monsoon season. Contiguous with Pulicat lake receiving inflows during the monsoon, and during spring tides during the dry season. Dries up during other periods
Sateneru-Sidimuthu Kayya	Creek with inlet/outlet into the Bay of Bengal	*c.* 100 ha; 150 cm	Algal mats	Perennial, but upper reaches dry up during the post monsoon. The Satenuru-Sidimuthu Kayya receives the overflow of the Urugayya lake and Madugu Vagu during the peak NE Monsoon season. Except for the peak monsoon period, the water in the kayyas is saline, receiving inflows from the Bay of Bengal during high tides
Urugayya	Brackish water-Saline Lake	*c.* 100 ha; 300 cm	Algal mats	Perennial, flows into the Sateneru-Sidimuthu Kayya during the peak NE Monsoon season

feeder, *Esomus danricus*, which was rarely encountered in the other freshwater bodies, was abundant in some abandoned irrigation ponds. However, *Esomus danricus* was a common species in water bodies on the mainland as well.

Penubakkam Baadava and Penubakkam Basin: A total of 15 species were recorded in the freshwater Penubakkam Baadava (Table 5) and 14 species in the brackish-saline Penubakkam Basin (Table 6). Fishes recorded in the Penubakkam Baadava, comprised of 10 freshwater and 5 brackish water species – the brackish water species originating from the Penumbakkam Basin into which it flows at the lower reaches. Species recorded in the Penumbakkam

Table 2: Checklist of the fish fauna of Sriharikota Island

Common Name	Freshwater Wetlands	Freshwater-Brackish water Wetlands*	Brackish water-Saline Wetlands**
Subdivision: Elopomorpha			
Order: Elopiformes			
Family: Elopidae			
Giant Herring *Elops machnata* (Forsskal)	-	#	#
Family: Megalopidae			
Oxeye Tarpon *Megalops cyprinoides* (Broussonet)	+	+	+
Order: Angulliformes			
Family: Angullidae			
Longfin Eel *Anguilla bengalensis* (Gray)	-	+	+
Shortfin Eel *Anguilla bicolor* McClelland	-	+	+
Family: Ophichthidae			
Paddy Snake-Eel *Pisodonophis boro* (Ham.-Buch.)	-	#	#
Subdivision: Ostarioclupeomorpha			
Superorder: Clupeomorpha			
Order: Clupeiformes			
Family: Clupeidae			
Subfamily: Dorosomatinae			
Bloch's Gizzard-Shad *Nematalosa nasus* (Bloch)	-	-	+
Superorder: Ostariophysi			
Series: Anotophysi			
Order: Gonorhynchiformes			
Family: Chanidae			
Milkfish *Chanos chanos* (Forsskal)	-	#	#
Series: Otophysi			
Order: Cypriniformes			
Family: Cyprinidae			
Subfamily: Danioninae			
Common Flying-Barb *Esomus danricus* (Ham.-Buch.)	+	-	-
Subfamily: Cyprininae			
Spotfin Swamp Barb *Puntius sophore* (Ham.-Buch.)	+	+	-
Family: Cobitidae			
Malabar Loach *Lepidocephalus thermalis* (Val.)	+	-	-
Order: Siluriformes			
Family: Bagridae			
Long-whiskered Catfish *Mystus gulio* (Ham.-Buch.)	-	+	+
Striped Dwarf Catfish *Mystus vittatus* (Bloch)	+	-	-
Family: Clariidae			
Magur *Clarias batrachus* (Linn.)	+	-	-
Family: Heteropneustidae			
Stinging Catfish *Heteropneustes fossilis* (Bloch)	+	-	-
Family: Ariidae			
Threadfin Sea-Catfish *Arius arius* (Ham.-Buch.)	-	#	#
Family: Plotosidae			
Canine Eel-Catfish *Plotosus canius* (Ham.-Buch.)	-	#	#
Series: Atherinomorpha			
Order: Beloniformes			
Family: Hemiramphidae			
Contaguri Halfbeak *Hyporhamphus limbatus* (Val.)	-	-	+
Family: Belonidae			
Spot-tail Garfish *Strongylura strongylura* (V. Hasselt)	-	-	+
Family: Adrianichthyidae			
Carnatic Ricefish *Oryzias carnaticus* (Jerdon)	+	+	+

Table 2: Checklist of the fish fauna of Sriharikota Island (*contd.*)

Common Name	Freshwater Wetlands	Freshwater-Brackish water Wetlands*	Brackish water-Saline Wetlands**
Order: Cyprinodontiformes			
Family: Aplocheilidae			
Dwarf Panchax *Aplocheilus parvus* Raj	+	+	+
Series: Percomorpha			
Order: Scorpaeniformes			
Family: Platycephalidae			
Bartail Flathead *Platycephalus indicus* (Linn.)	-	#	+
Order: Perciformes			
Suborder: Percoidei			
Family: Latidae			
Barramundi *Lates calcarifer* (Bloch)	-	+	+
Family: Ambassidae			
Commerson's Glassy Perchlet *Ambassis ambassis* Cuvier	-	+	+
Bald Glassy Perchlet *Ambassis gymnocephalus* (Lacepede)	-	-	+
Indian Glassfish *Parambassis ranga* (Ham.-Buch.)	+	-	+
Family: Terapontidae			
Target Terapon *Terapon jarbua* (Forsskal)	-	+	+
Family: Sillaginidae			
Silver Silago *Sillago sihama* (Forsskal)	-	#	#
Family: Carangidae			
Six-banded Trevally *Caranx sexfasciatus* (Quoy & Gaimard)	-	#	+
Family: Lutjanidae			
River Snapper *Lutjanus argentimaculatus* (Forsskal)	-	+	-
Family: Gerreidae			
Whiptail Silver-Biddy *Gerres filamentosus* (Cuvier)	-	#	+
Black-tipped Silver-Biddy *Gerres lucidus* Cuvier	-	#	+
Family: Scatophagidae			
Spotted Scat *Scatophagus argus* (Linn.)	-	#	#
Suborder: Labroidei			
Family: Cichlidae			
Orange Chromide *Etroplus maculatus* (Bloch)	+	+	+
Banded Pearlspot *Etroplus suratensis* (Bloch)	-	+	+
Mozambique Tilapia *Oreochromis mossambicus* (Peters)	+	+	+
Series: Mugilomorpha			
Order: Mugiliformes			
Family: Mugilidae			
Greenback Mullet *Liza subviridus* (Val.)	-	+	+
Flathead Mullet *Mugil cephalus* (Linn.)	-	+	+
Suborder: Gobioidei			
Family: Gobiidae			
Bighead Goby *Drombus globiceps* Hora	-	-	+
Tropical Sand Goby *Favonigobius reichei* (Bleeker)	-	-	+
Tank Goby *Glossogobius giuris* (Ham.-Buch.)	+	+	+
Sharptail Goby *Oligolepis acutipennis* (Val.)	-	+	-
Javanese Goby *Pseudogobius javanicus* (Bleeker)	-	+	+
Barred Goby *Pseudogobius poicilosoma* (Bleeker)	-	-	+
Family: Eleotrididae			
Broadhead Sleeper *Eleotris melanosoma* Bleeker	-	+	+
Suborder: Anabantoidei			
Family: Anabantidae			
Indian Climbing Perch *Anabas testudineus* (Bloch)	+	+	-
Family: Osphronemidae			
Subfamily: Macropodinae			
Spike-tailed Paradisefish *Pseudosphronemus cupanus* (Val.)	+	+	-

Table 2: Checklist of the fish fauna of Sriharikota Island (*contd.*)

Common Name	Freshwater Wetlands	Freshwater-Brackishwater Wetlands*	Brackishwater-Saline Wetlands**
Family: Osphronemidae			
Subfamily: Luciocephalinae			
Dwarf Gouramy *Colisa lalia* (Ham.-Buch.)	+	-	-
Suborder: Channoidei			
Family: Channidae			
Spotted Snakehead *Channa punctatus* (Bloch)	+	+	-
Striped Snakehead *Channa striatus* (Bloch)	+	+	-
Order: Synbranchiformes			
Family: Mastacembelidae			
Striped Spinyeel *Macrognathus pancalus* (Ham.-Buch.)	#	-	-
Order: Pleuronectiformes			
Family: Soleidae			
Oriental Sole Brachirus *orientalis* (Bloch & Schn.)	-	#	#
Order: Tetraodontiformes			
Family: Tricanthidae			
Short-nose Tripodfish *Triacanthus biaculeatus* (Bloch)	-	#	+
Family: Tetraodontidae			
Patoka Pufferfish *Chelonodon patoca* (Ham.-Buch.)	-	+	+
Species recorded	18	25	31
Additional species reported by fishermen	1	13	8
Total	19	38	39

* Freshwater stretches or/and becomes fresh during the peak monsoon; brackish water otherwise (Malliplate Vagu).

** Brackish water during the peak monsoon and turns saline as summer progresses (Urugayya).

In the case of creeks, the salinity increase is primarily due to inflows from the Bay of Bengal (Sateneru-Sidimuthu Kayya) or Pulicat Lake (Penubakkam Basin).

+ = recorded; - = not recorded; # = reported by fishermen

Basin (which borders Pulicat lake) were brackish, brackish-tolerant and marine species. The only records of *Parambassis ranga* in Sriharikota were from the Penumbakkam Baadava-Basin. Fishermen on the mainland, but not Sriharikota, were aware of this species.

Malliplate Vagu: Twenty-nine species were recorded from Malliplate Vagu (or Mavalam Vagu) comprising largely of freshwater and brackish water species (Table 7). The maximum number of gobioid species (7) were recorded from this stream. There are high possibilities of missing species in Malliplate due to the depth, debris, litter and silt along most of its course which made the sampling extremely difficult.

Urugayya: Twenty-six species were recorded from Urugayya lake (or Chola Doruvu) comprising predominantly of brackish water and marine forms (Table 8). Some freshwater groups (barbs and snakeheads) were also recorded during the peak NE Monsoon, probably originating from the nearby Madugu Doruvu, but these soon died out. *Drombus globiceps*, common in Urugayya lake, was not recorded in any other water body in Sriharikota or in Pulicat lake. Like the Malliplate Vagu, there are possibilities of missing species in Urugayya lake also, due to its depth. Local fishers reported the occurrence of many other species in Urugayya lake, including *Elops machnata*, *Megalops cyprinoides*, *Nematalosa nasus*, *Chanos chanos*, *Caranx sexfasciatus*, *Scatophagus argus* and *Chelonodon patoca* all of which were marine and/or secondary freshwater forms.

Sateneru-Sidimuthu Kayya: Twenty species were recorded in the Sateneru-Sidimuthu Kayya (Table 9). As this waterbody, mainly serves as an outflow of the Urugayya lake (and to a lesser extent the Madugu Vagu) into the Bay of Bengal during the NE Monsoon, the species composition is similar to Urugayya, but species richness was less due to its overall shallow nature and drying over large stretches during the dry season.

DISCUSSION

The Zoological Survey of India (ZSI), which had made collections in Pulicat lake during 1963, and subsequently between 1971 to 1975, recorded a total of 88 species (Rema Devi *et al.* 2004). We recorded 22 of these 88 species in

Table 3: Fish species recorded in Pedda and Chinna vagus

Species	Rod and Line n = 6	Gill net n = 12 net	Cast net n = 4	Draining Pools n =14	General Collections
Megalops cyprinoides	-	2.4 ± 5.7	-	1.9 ± 7.1	-
Esomus danricus	-	-	-	-	+
Puntius sophore	1.7 ± 2.7	0.1 ± 0.3	0.5 ± 1.0	40.9 ± 61.9	-
Mystus vittatus	-	-	-	5.4 ± 19.8	-
Clarias batrachus	-	0.1 ± 0.3	-	-	-
Oryzias carnaticus	-	-	-	-	+
Aplocheilus parvus	-	-	-	-	+
Heteropneustes fossilis	-	-	8.8 ± 8.5	6.6 ± 16.4	-
Oreochromis mossambicus	2.7 ± 3.9	12.6± 14.5	-	1.9 ± 5.4	-
Glossogobius giuris	-	-	-	0.1 ± 0.2	-
Anabas testudineus	-	1.3 ± 3.6	1.3 ± 0.5	8.4 ± 10.9	-
Pseudosphromenus cupanus	-	-	-	-	+
Colisa lalia	-	-	-	0.3 ± 1.2	-
Channa punctatus	2.5 ± 2.4	4.7 ± 6.1	4.5 ± 2.4	98.0 ± 145.5	-
Channa striatus	-	0.5 ± 1.2	0.3 ± 0.5	25.8 ± 77.0	-

Rod and Line: One rod and line was used on 6 days for duration of 3 hours each.
Gill-Net: One gill net was used on 12 days for duration of 2 hours each.
Cast-Net: One cast net was used on 4 days with 15 casts per trip.
Draining Pools: Denotes 14 pools drained by fishermen.
+ = incidental records during field trips, collection trips, and examination of fishermen's catches.
Values are means of catches, followed by the standard deviation.

Sriharikota Island and also recorded another 31 species not reported by the ZSI. However, comparisons between these two areas are unjustifiable as Pulicat lake is a brackish-saline ecosystem with mudflats, while Sriharikota has a variety of aquatic habitat types, including freshwater lakes and streams. However, 17 species of brackish-marine migratory fishes that were not recorded by the ZSI, including common species such as *Etroplus maculatus* and *Lates calcarifer* were encountered in the present study. There could have been possibilities of recording more and especially nocturnal species if sampling was also carried out at night.

The only endangered (CAMP 1998) freshwater fish species, occurring in Sriharikota is *Anguilla bengalensis*. Another *Anguilla* species reported to be less common in the study area by local fishers, but not evaluated by CAMP (1998), is *A. bicolor*. Species listed as vulnerable (CAMP 1998) and found in Sriharikota were *Clarias batrachus*, *Mystus vittatus* and *Anabas testudineus*. CAMP (1998) listed 329 freshwater species in India, leaving *c.* 300 others unassessed for their conservation status. A rare brackish water species (only half a dozen records of single individuals) of Sriharikota, which could possibly be listed as a threatened species in future assessments is *Eleotris melanosoma*. An endemic species of India, *Drombus globiceps*, originally reported from Chilika lake (Orissa) and subsequently from Ennore Estuary, Chennai (Rema Devi 1992), and Sankaraparani river, South Arcot District, Tamil Nadu (Rema Devi *et al*. 1996), was common in Urugayya. An exotic, native to Africa, the Mozambique Tilapia *Oreochromis mossambicus* and a non-native species, Dwarf Gouramy *Colisa lalia*, earlier known only from drainages in North India but now well-established in southern India (discussed under conservation issues) were recorded from the Island.

Table 4: Fish species recorded in abandoned irrigation ponds

Species	Rod and Line n = 8	Draining Pools n = 4
Esomus danricus	-	+
Puntius sophore	-	60.0 ± 73.5
Mystus vittatus	0.3 ± 0.7	12.8 ± 24.8
Clarias batrachus	0.8 ± 1.5	7.8 ± 14.8
Heteropneustes fossilis	-	0.3 ± 0.5
Oryzias carnaticus	-	+
Aplocheilus parvus	-	+
Oreochromis mossambicus	0.9 ± 1.5	-
Anabas testudineus	3.0 ± 3.8	4.0 ± 7.3
Pseudosphromenus cupanus		+
Channa punctatus	4.1 ± 3.5	42.5 ± 33.0
Channa striatus	0.1 ± 0.4	-

Refer notes in Table 3

The fish species diversity was much higher in Malliplate Vagu and Urugayya than other wetlands. The Malliplate Vagu has fresh and brackish water stretches and also receives seawater inflow at the mouth's stretch that opens into the Bay of Bengal. It has high habitat diversity with dense aquatic vegetation and reeds in the sandy lake-like upper reaches known as Katangayya, and debris and silt laden marsh-like conditions with insignificant aquatic vegetation in the lower reaches. Its perennial nature (except for the Katangayya part) and seasonal connectivity to the Bay of Bengal also contribute to the high fish species diversity. Thus, the fish fauna comprised of freshwater, brackish water and marine groups such as gobies, eels, cichlids, catfish, mullets and perches, and typical freshwater groups such as barbs and murrels (snakeheads).

Urugayya is a sandy-bottom, clear water lake with a maximum depth of *c.* 3 m. It lacks aquatic vegetation except for algae. The fish fauna is somewhat similar to Malliplate Vagu but with hardly any freshwater species, as those that move into it during the NE Monsoon die out quickly as the salinity increases with the cessation of rains. Urugayya is reported to have dried up only twice in the last 50 years due to severe drought. When this happened, its bed was found riddled with burrows of eels, revealing its importance as a habitat for eels. There is also a fishing season for prawns in the lake just after the monsoon.

The freshwater Pedda and Chinna vagus, and the rarely visited Madugu Doruvu and Vagu, primarily support freshwater species. The Chinna Vagu dries up completely during summer; the Pedda Vagu also dries along most of its course. Even the deeper regions dry up if the following SW Monsoon is delayed or fails, and if so, fish remain only in the perennial two kilometer fresh-brackish water stretch at its southern end. This portion gets connected periodically to the Bay of Bengal and the species composition is similar to Malliplate Vagu.

The Penubakkam Badava is a seasonal freshwater body. Freshwater fish species move into it from the Pedda and Chinna vagus and the abandoned irrigation ponds. Brackish water-marine species also move in from Pulicat lake (via the Penubakkam Basin) during the NE Monsoon. The Penubakkam Basin is an interface between Pulicat lake and Penubakkam Baadava with the fish fauna comprising of brackish water and marine species, the freshwater species dying out as soon as salinity increases during dry spells during the monsoon and post monsoon. The Penumbakkam Basin may also receive water (and fish) from Pulicat lake during the SW Monsoon if the influx of water is significant. A similar waterbody, the Beripeta Basin, was not sampled as it is more prone to drying and is more like an extension of Pulicat lake into the Island. The Sateneru-Sidimuthu Kayya is similar to Penumbakkam Basin with regard to its habitat, but the fish fauna comprises of only brackish-marine species as it opens into the Bay of Bengal. Freshwater species that may move into it during flooding die out quickly as the salinity increases.

An artificial aquatic habitat in Sriharikota is the abandoned irrigation pond. These are small deep ponds dug in the low-lying western border of the Island from Penubakkam in the north to Tettipeta in the south. The ponds were used to irrigate the paddy crop and also served as fish ponds. Many of the ponds are perennial, and the fish recruitment in ponds that dry up during summer is via the

Table 5: Fish species recorded in Penubakkam Baadava

Species	Rod and Line	Draining Pools	General Collections
Puntius sophore	-	42.5 ± 72.3	-
Esomus danricus	-	-	+
Mystus vittatus	-	0.8 ± 1.5	-
Clarias batrachus	-	1.0 ± 2.0	-
Heteropneustes fossilis	-	10.8 ± 9.4	-
Oryzias carnaticus	-	-	+
Aplocheilus parvus	-	-	+
Parambassis ranga	-	-	+
Etroplus maculates	0.2 ± 0.4	-	-
Oreochromis mossambicus	7.0 ± 8.2	7.5 ± 15.0	-
Anabas testudineus	0.4 ± 0.9	20.0 ± 18.3	-
Pseudosphromenus cupanus	-	-	+
Colisa lalia	-	-	+
Channa punctatus	0.4 ± 0.5	81.3 ± 98.7	-
Channa striatus	-	0.5 ± 1.0	-

Refer notes in Table 3

Table 6: Fish species recorded in Penubakam Basin

Species	Gill-net n = 9	General Collections
Nematalosa nasus	8.2 ± 5.5	-
Mystus gulio	2.3 ± 3.8	-
Hyporhamphus limbatus	-	+
Strongylura strongylura	-	+
Oryzias carnaticus	-	+
Aplocheilus parvus	-	+
Parambassis ranga	-	+
Gerres lucidus	0.9 ± 1.4	-
Oreochromis mossambicus	18.0 ± 13.0	-
Etroplus maculates	-	+
Etroplus suratensis	-	+
Liza subviridus	13.4 ± 8.9	-
Mugil cephalus	1.7 ± 3.3	-
Pseudogobius javanicus	-	+

Refer notes in Table 3

Table 7: Fish species recorded in Malliplate Vagu

Species	Rod and Line n = 22	Gill-net n = 27	General Collections
Megalops cyprinoids	0.1 ± 0.3	0.3 ± 0.7	-
Anguilla bengalensis	0.1 ± 0.4	-	-
Anguilla bicolor	-		+
Puntius sophore	0.3 ± 1.3	0.2 ± 0.6	-
Mystus gulio	2.3 ± 2.7	1.2 ± 3.0	-
Oryzias carnaticus	-		+
Aplocheilus parvus	-		+
Lates calcarifer	-	0.04 ± 0.2	-
Ambassis ambassis	1.7 ± 4.7	0.6 ± 1.2	-
Terapon jarbua	2.8 ± 3.1	0.7 ± 1.8	-
Caranx sexfasciatus	-	0.3 ± 1.0	-
Lutjanus argentimaculatus	-	0.04 ± 0.2	-
Gerres lucidus	-	0.04 ± 0.2	-
Etroplus maculatus	0.2 ± 0.7	-	-
Etroplus suratensis	1.9 ± 3.4	0.6 ± 1.4	-
Oreochromis mossambicus	3.4 ± 5.1	27.4 ± 22.0	-
Liza subviridus		5.6 ± 17.7	-
Mugil cephalus		5.2 ± 7.8	-
Pappillogobius reichei	-	-	+
Glossogobius giuris	-	0.04 ± 0.2	-
Oligolepis acutipennis	-	-	+
Pseudogobius javanicus	-	-	+
Pseudogobius poicilosoma	-	-	+
Eleotris melanosoma	-	-	+
Anabas testudineus	-	1.0 ± 4.8	-
Pseudosphromenus cupanus	-	-	+
Channa punctatus	0.9 ± 3.5	0.04 ± 0.2	-
Channa striatus	0.6 ± 2.2	0.6 ± 2.1	-
Chelonodon patoca	-	-	+

Refer notes in Table 3

Table 8: Fish species recorded in Urugayya

Species	Conical Prawn-net n = 8	Gill-net n = 21	General Collections
Megalops cyprinoides	-	0.05 ± 0.2	-
Anguilla bengalensis		-	+
Anguilla bicolor	0.1 ± 0.4	-	-
Mystus gulio	0.8 ± 1.2	0.05 ± 0.2	-
Puntius sophore	-	-	+
Strongylura strongylura	-	0.05 ± 0.2	-
Oryzias carnaticus	-	-	+
Aplocheilus parvus	-	-	+
Lates calcarifer	-	0.05 ± 0.2	-
Platycephalus indicus	0.1 ± 0.4	-	-
Ambassis gymnocephalus	1.6 ± 2.3	-	-
Terapon jarbua	1.3 ± 3.5	0.2 ± 0.9	-
Gerres lucidus	15.5 ± 30.5	0.7 ± 1.6	-
Etroplus maculatus	1.4 ± 1.5	1.6 ± 1.9	-
Etroplus suratensis	3.5 ± 1.8	1.8 ± 1.6	-
Oreochromis mossambicus	1.5 ± 2.5	4.7 ± 3.1	-
Liza subviridis	0.5 ± 1.4	0.5 ± 2.2	-
Mugil cephalus	-	0.8 ± 3.1	-
Glossogobius giuris	0.4 ± 1.1	0.05 ± 0.2	
Drombus globiceps	-	-	+
Favonigobius reichei	-	-	+
Pseudogobius javanicus	-	-	+
Pseudogobius poicilosoma	-	-	+
Eleotris melanosoma	-	-	+
Channa punctatus	-	-	+
Triacanthus biaculeatus	0.5 ± 0.9	-	-

Refer notes in Table 3

basin that gets connected to the other perennial irrigation ponds and other wetlands of the Island. The fish fauna of these ponds are dominated by air-breathing fishes like *Anabas testudineus*, *Clarias batrachus* and *Heteropneustes fossilis*, which can survive in murky and less oxygenated waters. Brackish water species that may move in from Pulicat lake during the peak monsoon and non-air breathing species cannot survive in the ponds as they are heavily silted and engulfed by water hyacinth and cane, resulting in low dissolved oxygen content.

CONSERVATION ISSUES

Overall, the studies revealed that Sriharikota has a variety of fairly well-protected, wetland habitats, ranging from freshwater to marine, that support a diversity of fish fauna including endangered' and vulnerable species. However, there are conservation issues facing the wetlands including proliferation of invasive species, siltation and over-exploitation, which are discussed below:

Cane: Cane, *Calamus rotang* was introduced in Sriharikota in 1882-83 during the British Era (Reddy 1981). It is now seen around all freshwater habitats, engulfing the smaller ones and forming impenetrable brakes in streams obstructing the water flow. According to the tribals, cane proliferated after ISRO stopped its exploitation on takeover of the Island. To generate employment for the tribals, the SDSC started extraction of cane in 2002, but this has not made a significant impact till now, and may take a few years to witness a decline. Otherwise, cane will have to be eradicated or its spread checked to save the wetlands.

Water Hyacinth: The exotic aquatic weed, water hyacinth *Eichhornia crassipes* has almost completely covered the surface of many abandoned irrigation ponds, especially the perennial ponds in the northern areas. The mat-like

formations over the water prevent sunlight and oxygen reaching the water column and submerged plant causes oxygen depletion affecting fisheries (Naskar 1990). For this reason, the fish fauna in abandoned irrigation ponds were found to comprise primarily of hardy, air-breathing fishes. Eradication of water hyacinth in Sriharikota is not a difficult task as the ponds are small in size and the species occurs only in (some) abandoned irrigation ponds and nowhere else in the Island.

Ipomoea carnea: Another South American aquatic species that is now a major weed in India is *Ipomoea carnea* (Chaudhuri *et al.* 1994). The species was also recorded in Sriharikota, but unlike some wetlands on the mainland where it is a problem, it occurs only in patches at the edges of some wetlands. One reason for this could be dominance of cane along the edges of freshwater bodies. However, the species will have to be monitored to see if it turns out to be an invasive.

Siltation: Siltation is a major problem confronting abandoned irrigation ponds, the Madugu Doruvu and Pedda and Chinna vagus. According to the locals, desilting operations used to be taken up once every few years in the irrigation ponds and deeper regions of the Pedda and Chinna vagus (which were maintained as fish ponds) prior to the takeover of the Island by ISRO. The silt collected was used in crop fields. Along with the spread of cane, some of the smaller freshwater bodies have almost disappeared with the build-up of silt. On our recommendations, the authorities of SDSC have started de-silting stretches of the Pedda and Chinna vagus, which will help restore the streams.

Table 9: Fish species recorded in Sateneru-Sidimuthu Kayya

Species	Gill-net n =8	General Collections
Nematolosa nasus	2.5 ± 3.1	-
Mystus gulio	0.3 ± 0.5	-
Oryzias carnaticus	-	+
Aplocheilus parvus	-	+
Platycephalus indicus	0.1 ± 0.4	-
Ambassis ambassis	0.4 ± 1.1	-
Terapon jarbua	2.4 ± 3.7	-
Caranx sexfasciatus	0.1 ± 0.4	-
Gerres lucidus	2.4 ± 3.7	-
Scatophagus argus	0.1 ± 0.4	-
Etroplus maculatus	0.8 ± 1.2	-
Etroplus suratensis	0.1 ± 0.4	-
Oreochromis mossambicus	8.9 ± 9.6	-
Liza subviridus	4.8 ± 4.9	-
Mugil cephalus	7.6 ± 6.6	
Drombus globiceps	-	+
Favonigobius reichei	-	+
Pseudogobius javanicus	-	+
Pseudogobius poicilosoma	-	+
Chelonodon patoca	0.1 ± 0.4	-

Refer notes in Table 3

Exotic/Non-native fish species: Two non-native fish species now occur in Sriharikota, namely Mozambique Tilapia *Oreochromis mossambicus* and Dwarf Gouramy *Colisa lalia.* The Mozambique Tilapia, first introduced as a food fish in India in 1952 and now widespread in many parts of southern India, occurs in freshwater and brackish water habitats and also tolerates high salinity (Jones and Sarojini 1952; Editors 1954; Daniels 2006). The species is now common in Pulicat lake and Sriharikota. The impact of this hardy species on the other species is unknown as affected species may have already disappeared or declined in numbers. The Dwarf Gouramy, a popular aquarium fish, is native of northern India (Talwar and Jhingran 1991; Jayaram 1999). It is now known to occur in the wild in Chennai, a major aquarium fish breeding centre in India (Daniels 2002, 2006), *c.* 40 km from the southern tip of Sriharikota. It could have come to Sriharikota via the Buckingham Canal during the peak NE Monsoon or through intentional or accidental introductions in the mainland waters and islands in Pulicat lake by aquarists and fish hobbyists. The species was found to be common in two village ponds in two islands of Pulicat lake. The species was rare in Sriharikota, and the local fishermen either did not know the species or said it was a new entrant to the Island. The only other similar same-sized species that it could possibly impact in Sriharikota is *Pseudosphromenus cupanus.* The Dwarf Gouramy is a small, peaceful and harmless aquarium species (Mondadori 1977), but competition for the same food and other resources could have an impact on native species and especially *P. cupanus.*

Fishing: Fishing was one of the major occupations of the locals till ISRO took over the Island. After its takeover, ISRO gave fishing rights to some tribals to earn their livelihood by selling fish to the employees of the SDSC. Fishing is on a low scale, but there are reports that outside contractors (illegally) supply the tribals with fishing gear to catch prawns and fish species that find a good market on the mainland. The demand for fish by the locals has also increased with the development of the spaceport and facilities over the years. However, there are definite plans by ISRO to completely shift the residential areas to the mainland, which will be a boon for the fish fauna.

Other than these conservation issues, another issue apparently concerning the freshwater fish fauna is they are more prone to extinction as these inhabit an island ecosystem. However, though the island is surrounded by the brackish-saline waters of Pulicat lake and the Bay of Bengal, Sriharikota gets connected to the freshwater wetland, streams and rivers of the mainland during the peak SW Monsoon season, as almost freshwater conditions prevail in Pulicat lake during the peak NE Monsoon season. Additionally, the

cyclonic storms that lash the region once in a few years result in massive flooding, permitting even the immigration of large mammals into the Island (Kannan and Manakadan 2004; Manakadan and Sivakumar 2004b).

ACKNOWLEDGEMENTS

We thank the Indian Space Research Organisation for funding the projects undertaken in Sriharikota, and especially late Prof. Satish Dhawan, former Chariman, ISRO, whose love for the wilderness was instrumental in the projects being conceptualized and getting sanctioned. We also thank ISRO authorities at the SDSC, Sriharikota, for providing us the necessary permission and other facilities for stay and to carry out field surveys. The paper has benefitted by perusal of drafts by V. Kannan, Vidyadhar Atkore and Patrick David, and especially from the comments and exhaustive corrections on the earlier drafts of this paper by the anonymous referee. And, last but not least, we thank our local assistant M. Parandamaiah for help during the fieldwork.

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DIVERSITY, CONSERVATION AND MANAGEMENT OF MAMMALS IN BAGO YOMA, RAKHINE YOMA AND ALAUNGDAW KATHAPA NATIONAL PARK IN MYANMAR

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This investigation was aimed to provide baseline data for the occurrence and diversity of mammals and their conservation status in Bago Yoma, Rakhine Yoma and Alaungdaw Kathapa National Park (AKNP) in Myanmar. Direct and indirect evidences of animals were assessed along transect lines, existing forest trails, waterholes, caves, from animal observation posts, and through village visits. A total of 33 species of mammals was reported across all the regions investigated and an average of 22.3 mammalian species per region was reported. Among these, 21% were classified as endangered, 21% as vulnerable, 7% as Data Deficient as per the IUCN (Menon 2003) Red list status; thus about 50% of the species reported had high conservation significance. Differences in mammalian diversity across all the regions investigated were not statistically significant. For every 5 individuals, a new species of mammal was encountered in AKNP; for Rakhine, this occurred for only every 12 individuals and in Bago for every 9 individuals. The percentage of all mammals, including large mammals and endangered species reported in Rakhine Yoma was high. Although the region surveyed was considered as being rich in mammal diversity, continuing commercial exploitation of the forest for the timber industry, destructive agricultural practices, and unrestricted hunting have resulted in rapid loss of natural habitat and a significant decline of wildlife.

Key words: large mammals, IUCN Red list, habitat modification, hunting, conservation significance

INTRODUCTION

Myanmar, covering a total land area of 677,577 sq. km, is known for its rich floral and faunal diversity (Wint 1993). The country is home to nearly 7,000 species of plants, 300 species of mammals, 1,000 species of birds, about 360 species of reptiles and other taxa, which are poorly documented (IUCN 1989). Conservation of nature is a tradition among the people of Myanmar (Htut 1993). However, wildlife in Myanmar suffered greatly during the Second World War (IUCN 1989; Htut 1993). Even after independence, it suffered a great deal from issues such as insurrection and ineffective law enforcement, and consequently, large mammals, particularly the Asian Elephant *Elephas maximus* and the Tiger *Panthera tigris* today face serious threats for survival (IUCN 1989; Htut 1993), while the Sumatran Rhinoceros *Didermocerus sumatrensis* is very close to extinction (Salter 1983; Rabinowitz and Schaller 1995).

Bago Yoma, located in central Myanmar, has been recognised as being rich in wildlife and containing the largest and most valuable block of Teak forest in the world (Uga 1995). The FAO/UNDP survey carried out in 1981 (FAO 1982) suggested that within Bago Yoma the entire Yenwe catchment upstream of the dam and the rich wildlife habitat in north of Zamari needed protection. Proposing a protected area of not less than 320,000 acres, FAO (1982) recommended that the Yoma be protected as an instance of outstanding landscape and also as a habitat of rare animals, such as the Serow *Nemorhaedus sumatraensis*.

Rakhine Yoma located in the western region of the country has greater number of endangered and vulnerable species, making it a more important region for large mammal conservation (Sayer 1983). According to Sayer (1983), the rugged topography and dense vegetation cover in the Rakhine region made it difficult to hunt animals enabling existence of a diverse animal population. He also felt the reduced presence of settlements/clearings in the forest was due to the low agricultural value of the land.

The Alaungdaw Kathapa National Park (AKNP), located in northern Myanmar still has a large area under forest cover, harbouring the endangered Eld's Deer (*Cervus eldi*) along with other species of large mammals (Tun 1997).

Although the regions have been considered to be rich in mammal diversity, since 1856, under sustainable management of forests, intensive timber extraction has been practiced in these regions. The commercial exploitation of forests on 30 years of felling cycle for 130 yrs for the timber industry have negative effects. In addition, the destructive agricultural practices, and unrestricted hunting have resulted in significant wildlife decline and rapid loss of natural habitats and has resulted in a large area being occupied by Bamboo spp. (Salter 1983; Uga 1995; Tun 1997; Rao *et al.* 2002).

Effective wildlife conservation and management

programs are yet to make an impact in these regions. Only in 1997, 1,775 sq. km (out of 16,000 sq. km area of Rakhine Yoma) area was gazetted as Rakhine Yoma Wildlife Sanctuary (Uga 1995; Rao *et al.* 2002). Under the Bago Yoma Teak Nature Reserve (covering 1,500 sq. km), there was a proposal to preserve the pristine nature of the teak and other forests. To fulfill this objective a survey was conducted in 1983, however, the areas are yet to be brought under the legal management system. AKNP one of the oldest forested regions of the country, was legally gazetted as a Wildlife Sanctuary only in 1984.

Evaluating the status of animals and their habitat in Myanmar is difficult as visibility within the forests is very poor and many of the forests are inaccessible. The survey regions are very remote, with rugged terrain, infested with mosquitoes carrying malaria, and non-existent or extremely poor logistical facilities, making direct observation of animals extremely difficult. However, these regions are very important due to the presence of globally threatened species (Salter 1983; IUCN 1989; Htut 1993). Therefore, observation of tracks, defecation and other signs, along with information collected from local hunters and villagers were used to provide basic data on the occurrence and status of the animal species found in these regions (FAO 1982; Salter 1983; IUCN 1989; Htut 1993; Uga 1995; Rao *et al.* 2002).

For a country like Myanmar, to specifically assess the status of animals found in different regions is never easy given the constraints of time, manpower and other resources available, and the difficulties associated with carrying out a survey in most of the region. A study on the status of the Asian Elephant and its conservation was initiated in Myanmar in the regions of Bago Yoma (formerly known as Pegu Yoma), Rakhine Yoma (formerly known as Arakkan Yoma), and the Alaungdaw Kathapa National Park (AKNP) of northern Myanmar. The areas were chosen as they are considered to be important regions for elephants (FAO 1982; Salter 1983; Htut 1993; Myint 1994; Tun 1997).

The elephant survey provided an opportunity for investigations on the presence and relative abundance of mammalian species, trends of species diversity, similarity and conservation status of mammals and their habitats in these regions. Conservation of mammals, including Asian elephants, in survey regions or for an entire country is possible only through knowing their presence and absence or reviewing the current management status of these regions. The investigation was also aimed at reviewing the establishment of protected areas, staff strength, status of hunting, annual net deforestation rate, legislation to protect mammals and their habitat, law enforcement, budget, and land use polices. Myanmar still contains large areas of relatively intact forest (Rao *et al.* 2005), as one-third of the country's total area is still under forest cover (Aung 2007) coupled with a low human population density and impact (Sanderson *et al.* 2002). Relative importance of these factors and their scope for conservation of mammals and their environment is also discussed through this survey.

MATERIAL AND METHODS

Investigation sites

The investigation sites (Fig. 1) were Bago Yoma (17°-20° N; 96°-97° E), Rakhine Yoma (17°-21° N; 93°-95° E), and Alaungdaw Kathapa National Park (AKNP) (22°-23° N; 94°-95° E). The Bago, Rakhine, and AKNP regions, situated in the central, western and northern regions of Myanmar, respectively, have very extensive tracts of hills. The hill ranges of Rakhine Yoma are a southward extension of the Himalayas. AKNP is in a well-forested mountainous region, situated west of the lower Chindwin river and the Myittha valley. The average elevation of the Bago Yoma is about 700 m; the highest point is 900 m above msl. In Rakhine Yoma, which runs for nearly 600 km, the height ranges between 1,000 and 1,400 m above msl and the average elevation in AKNP is about 1,000 m (ranging between 200 and 1,400 m); steep slopes and narrow ridges characterise all regions.

All these regions have good drainage systems: the Pegu and tributaries of Yenwe Chaung, and the Kun Chaung are the major river sources in Bago Yoma. The Sandoway river (Sandoway Chaung) is the major river system in Rakhine. AKNP is drained by a number of tributaries of the Patolon river, the Petpa Chaung and Taungdwin Chaung being perennial. In all these regions, the wet season lasts from May to October, and is heaviest in August and September. The annual mean rainfall for Bago is 1,700 mm, for Rakhine it is 1,800 mm and for AKNP it is 1,500 mm. In all these regions, the vegetation is largely mixed deciduous forest, with semi-evergreen forests occurring in areas of high precipitation. Patches of evergreen trees consisting, mostly of secondary growth occur in a few places.

The mammalian species reported in these regions include the Rhesus Macaque *Macaca mulatta*, Hoolock Gibbon *Hylobates hoolock*, Phayre's Langur *Semnopithecus phayrei*, Sambar *Cervus unicolor*, Barking Deer *Muntiacus muntjac*, Hog Deer *Axis porcinus*, Eld's Deer *Cervus eldi*, Gaur *Bos gaurus*, Tsaine (Saing) or Banteng *Bos javanicus*, Serow *Nemorhaedus sumatraensis*, Elephant *Elephas maximus*, Sumatran Rhino *Dicerorhinus sumatrensis*, Asiatic Black Bear *Ursus thibetanus*, Malayan Sun Bear *Ursus malayanus*, Leopard *Panthera pardus*, Tiger *Panthera tigris*,

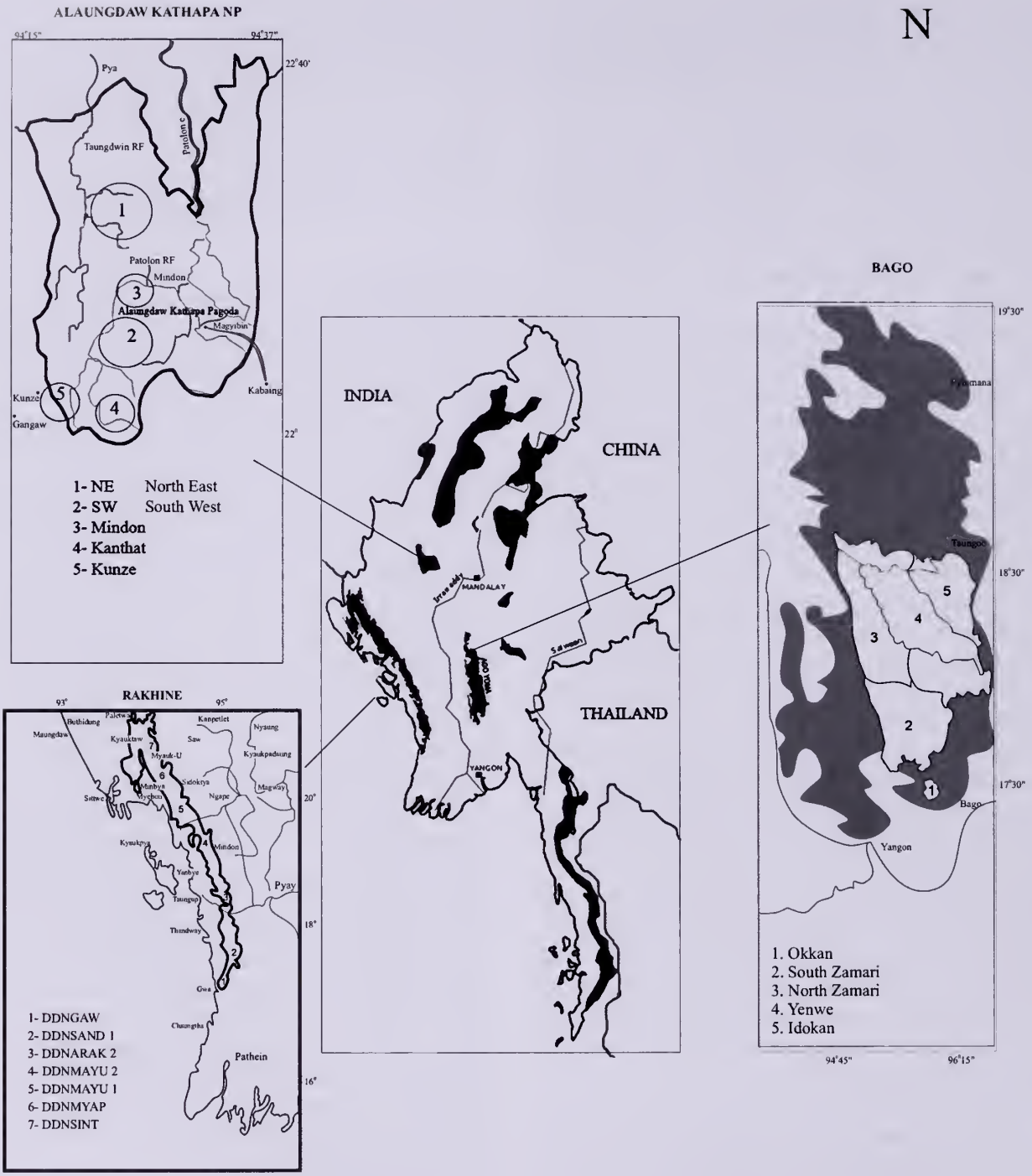

Fig 1: Survey sites in Myanmar: The sites are marked among the forested regions of the country

and Wild Dog *Cuon alpinus*. The sources for the common and scientific names are Corbet and Hill (1992), Yin (1993) and Menon (2003).

Besides the author, the study team for the Bago and Rakhine yoma were drawn largely from the Forest Department and Myanmar Timber Enterprise (MTE), which included Range Forest Officers, Rangers, and Deputy Rangers. In AKNP, the study was conducted with the help of a 14-member expedition team from the UK-based Scientific Exploration Society. Separate training programs for each region were conducted for the teams on various aspects of the investigation. The investigation was carried out in five reserves of the Bago Yoma – 1) South Zamari, 2) North Zamari, 3) Yenwe, 4) Idokan, and 5) Okkan. Seven forest reserves of the Rahine Yoma – 1) Part of Thandwe Reserved Forest (RF) (DDNSAND1), 2) Sabyin and Mindon

area (DDNARAKAN 2), 3) Part of Gwa RF (DDNGAW), 4) North of May Yu RF (DDNMAYU1), 5) south of May Yu RF (DDNMAYU2), 6) Part of Miva Pya (DDNMYAP), and 7) Part of Sin Tanung RF (DDNSINT) were studied. The locations within the AKNP were referred to as South-west (SW), North-west (NW), Mindon, Kunze and Kanthat. In each reserve, the team was split into a number of groups (each consisting of three to four persons, including a field tracker) and data was collected through various methods.

SURVEY METHODS

Line transect method

Direct and indirect evidence of animals was assessed along transect lines to record the species of animals, the number and frequency of occurrence, and their diversity. A total of 142 transects for Bago, 148 for Rakhine, and 22 for AKNP were laid. The length of transects in a particular reserve, within a region, was roughly proportional to the total area of the reserve and lines were well-distributed, covering different regions of the reserves sampled (Table 1). In a given site, not more than three subgroups operated to cut transects, and a minimum distance of 2 km was maintained between two subgroups.

Forest Trail survey method

Existing forest trails were considered for systematic sampling and the start time and end time of every forest or sampling route were noted. During this time, sightings of mammals were recorded through direct and indirect observation (vocalisation, tracks, signs, defecation and other evidence). At every sighting, the time of sighting, name (where possible) and numbers of the animal sighted or indirect evidence was recorded along with other features of the habitat. Whenever possible, the GPS location was noted and acetate transfers of tracks obtained.

Village survey method

The clearest indication of the abundance of wildlife could be obtained from the village survey, for which the systematic approach of a questionnaire-based survey was used in villages situated close to forests. A total of 89 villages were visited for this survey; 76% of the villages were located within the forests and 24% villages were located in a mean distance of 2.88 km (SE = 0.55) from the forests.

Other methods

Specific places such as waterholes, watch towers and animal observation posts were visited. Image Intensifier (II)

Table 1: Forest reserves sampled, area, number and percentage of transects surveyed and distance covered for Bago, Rakhine and AKNP regions

Regions	Name of Reserves	Area sq. km	%	No of transects	%	Distance covered (km)
Bago	South Zamari	882	29.9	36	25.4	72
	North Zamari	714	24.2	35	24.6	70
	Yenwe	795	26.9	36	25.4	72
	Idokan	521	17.6	23	16.2	46
	Okkan	40	1.4	12	8.5	23.5
	Total	**2952**		**142**		**283.5**
Rakhine	DDNSAND 1*	750.5	6.3	16	10.8	32
	DDNARAK 2 *	2600	21.9	70	47.3	140
	DDNGAW *	2600	21.9	20	13.5	40
	DDNMAYU 1*	2652.8	22.4	12	8.1	24
	DDNMAYU 2 *	1200	10.1	8	5.4	16
	DDNMYAP*	1750	14.8	12	8.1	24
	DDNSINT*	307.2	2.6	10	6.8	20
	Total	**11860.5**		**148**		**296**
AKNP	South-west			6	27.3	12
	North-west			4	18.2	8
	Mindon			4	18.2	6
	Kunze			4	18.2	8
	Kanthat			4	18.2	8
	Total	**1606**		**22**		**42**

*Part of Thandwe Reserved Forest (DDNSAND1), Sabyin & Mindon (DDNARAKAN2), part of Gwa Reserved Forest (DDNGWA), north of May Yu Reserved Forest (DDNMAYU1), south of May Yu Reserved Forest (DDNMAYU2), part of Miva Pya (DDNMYAP) and part of Sin Tanung Reserved Forests (DDNSINT).

was used and observations were made by selecting a site, depending on the visibility of the location, with a 50 m radius (The II device works on available light without magnification). Observations were made between 1930 and 2130 hrs. Apart from these methods; observations were also made by waiting for animals near rivers and streams (without II), and on journeys between camps from vehicles or while alighting from vehicles. Signs of animals were also observed in and around the camp, and while creating transects. Caves were visited to observe bats. Mist nets were set up over rivers and within the camp areas, and observers waited for at least an hour at each site, sometimes the wait extending up to two hours.

The ground investigation was initiated in 1995 and was continued till 2000, and the current information (since 2001) on the status of mammals and their habitat was based on personal communications (Uga and Hpone Thant (Harry)), and literature (James *et al.* 1999; Gutter 2001; Rao *et al.* 2002; Bennett and Rao 2002; Sanderson *et al.* 2002; Leimgruber *et al.* 2003, Aung *et al.* 2004; FAO 2004; Rao *et al.* 2005; Lynam *et al.* 2006; Aung 2007). The systematic investigations carried out for Bago were from May 1995 to December 1995, for Rakhine, from December 1995 to May 1996, and for AKNP, only in January 1999. Specific locations of Rakhine and Bago Yoma were investigated again in May 1998 and January 2000 respectively. An attempt to cover the northern Myanmar (regions such as Tamu, Homalin, Tamanthi and Tanai) was made in 2000, but insurgence and other logistic reasons made actual ground investigation impossible. Overall, a total of 8,100 man-hours in Rakhine, 8,500 man-hours in Bago, and 1,350 man-hours in AKNP, respectively, were spent on investigations.

Data analysis

Only the line transect, trail and village investigations provided meaningful observations; though considerable time was spent for observing animals using other approaches (observations with and without II, and using mist nets for bats), they did not provide much scope as number of animals observed through these approaches were substantially low. Results of all these methods were pooled together only to construct a species list, and their presence and absence in the regions sampled. Results of line transect sampling were used for arriving at the frequency occurrence, species diversity and similarity.

Initially, the total number of mammalian species encountered for all the regions together was computed and an overall mean number for species (with standard error – SE and % coefficient of variation – CV) was calculated for each region. Mammals were classified based on their size or weight, or a combination of both, also taking into consideration their mention in literature (Datta 1999; Shankar and Sukumar 1999; Nameer *et al.* 2001). Body length (head to base of tail) was given more importance as the weight of an animal could change depending on its food intake and other factors. Animals above 50 cm were considered large mammals, those between 20 and 40 cm were small/to medium size mammals, and animals below 20 cm were treated as small mammals with body size measurements based on Yin (1993) and Menon (2003).

The percentage of Endangered, Vulnerable and Data Deficient categories of the IUCN Red List (Menon 2003; IUCN 2007) was calculated to arrive at the conservation significance of each survey region. This was done in relation to the occurrence of different categories for all three regions taken together and also individually. Mammalian diversity and other associated parameters for each region were calculated using the computer program BIODIVERSITY Pro (McAleece *et al.* 1997). Diversity and species abundance calculated across the regions were tested using the Kruskal Wallis (Hc) test for significance, through the computer program PAST (Hammer *et al.* 2001).

The number and percentage of similar species shared (based on similarity matrix) across regions were calculated, more specifically large mammal similarity across different regions. This was based on a Bray-Cluster Analysis (Single line) using BIODIVERSITY Pro (McAleece *et al.* 1997). In addition, for each region, the mean percentage (with SE and % CV) of large mammals shared with other regions was calculated. For both these sections, the computation was done in relation to the occurrence of similar species across different regions, and surveys carried out in the same region at different times and in regions that had geographical and ecological similarities.

RESULTS

A total of 33 species of mammals were reported for all the three regions and an average of 22.3 (SE =1.8, CV % 7.9) mammalian species were reported for a region. A total of 15 species (45%) of large mammals was recorded for all the regions investigated, and 93% species were readily identifiable (Prater 1971; Corbet and Hill 1992; Yin 1993; Menon 2003). Among the species identified, 21% were classified as endangered, 21% vulnerable, and 7% belonged to the Data Deficient category of the IUCN Red List status; thus about 50% of the species were reported to have high conservation significance. A total of 14 species (42%) of small to medium sized mammals (Rabinowitz and Schaller 1995) were reported for the regions surveyed; 57% of them were identifiable either to genera or to species; only 42% were

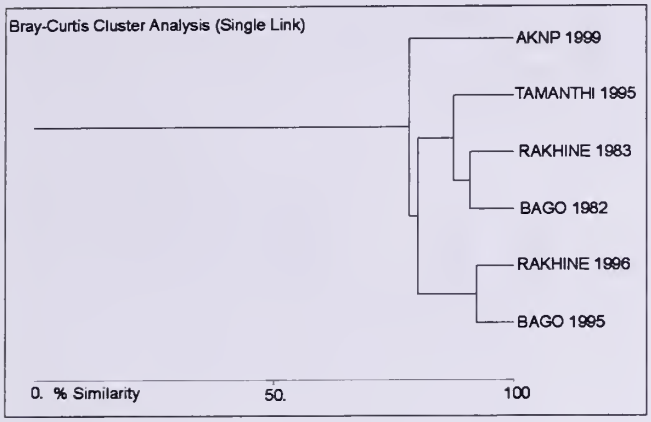

Fig. 2: Large mammal similarity across different regions of Myanmar; the results are based on Bray-Curtis Cluster Analysis (Single Link)

identifiable up to species level. Four species (12%) of small mammals were reported for these regions and none of them were identifiable (Table 2) by specific species name.

Significance of occurrence of mammalian species for different regions

Bago Yoma

A total of 22 species of mammals were identified for the Bago Yoma region (Table 2) of which 82% species were easily identifiable. Among all the species encountered, Barking Deer dominated (35%) for the region, followed by Sambar (17%), Capped Langur (12%), Gaur (9%), and Wild Boar (8%). Overall mammalian diversity value (H') for the region was 2.05 and the equitability value was 0.66 (Table 3). Bago Yoma, under IUCN Red list status, had three species of endangered, two species of vulnerable, and one species under the data deficient category (Table 2).

Rakhine Yoma

For Rakhine Yoma, 25 species of mammals were encountered (Table 2). The pattern of occurrence of different species followed the same trend as Bago Yoma, with the most frequently sighted mammal being the Barking Deer (31%), followed by Sambar (16%), Capped Langur (11%), Gaur (9%) and Wild Boar (8%). Overall mammalian diversity value (H') for the region was 2.18 and the equitability value was 0.67 (Table 3). Rakhine Yoma, under IUCN Red List status, had four species of endangered, three species of vulnerable and one species under the data deficient category.

AKNP

In AKNP, a total of 20 species was encountered (Table 2), of which 82% were readily identifiable. Overall large mammal diversity value (H') for the region was 2.5, and the equitability value was 0.83 (Table 3). AKNP under IUCN Red List status had only one species of endangered, three species of vulnerable, and one species under the data-deficient category (Table 2). The most frequently sighted mammal on all routes was the Gaur, followed by the Sambar, Wild Dog, Barking Deer and Leopard.

On the South-west route, both Gaur and Sambar were sighted with the same frequency. On the North-West route, Gaur was the most frequently sighted animal followed by Sambar and Wild Dog. No sightings or signs of primates were noticed. This could be due to the fact that they had been heavily hunted, or as the forest had been logged, not much tree cover was available for this arboreal taxon. All along the Mindon river, fish poisoning was noticed and the investigation team found bloated fish carcasses along the river.

Trend of species diversity reported across regions

Trend of species diversity and other parameters associated with it are presented in Table 3. The results of the differences across the diversity and abundance values across these regions were not statistically significant (for diversity value Hc=0, $p>0.01$; for abundance Hc=0.38, $p>0.01$) suggesting that mammalian diversity across these regions were equal. While in Rakhine, 18% of individuals were represented by a single species. In AKNP, only 11% individuals represented a single species. For every 5 individuals, one new species was encountered in AKNP, while in Rakhine this occurred in only every 12 individuals and in Bago, for every 9 individuals.

If we consider large mammal diversity and abundance exclusively across the surveyed region, the diversity and abundance were the same in all the regions as the differences were not statistically significant (for diversity, Hc=0, $p>0.01$; for abundance, Hc=0.12, $p>0.01$). Species dominance across Rakhine and AKNP was the same, and in both regions 19% individuals were represented by a single species. For every 8 individuals a new species of large mammal was reported for AKNP, while in Bago it was for every 15 individuals and in Rakhine for only every 19 individuals.

Trend of similar species reported across regions

The investigation results indicated that Bago and Rakhine shared 12 similar species of large mammals, and between Bago and AKNP 8 similar species were reported. The number of similar species shared by Rakhine and AKNP was 9. A specific examination of large mammal similarity across the region, at different times revealed that Bago and Rakhine had a similarity of 92%; while Bago and AKNP had 76%, and Rakhine and AKNP had 78%. Similarly, if one compares similarity over the years, then Bago 1982 and 1995 has species similarity of 69% while Rakhine 1983 and 1996 have 80%

Table 2: Mammal species recorded for the survey regions of Myanmar

S. No	Species category	Scientific name	Mammal	IUCN Red List status	Method of identification	Frequency of occurrence (%)		
						Bogo	Rakhine	AKNP
1	Capped Langur	*Trachypithecus pileatus*	LM	E	Direct	12.3	10.9	0
2	Tiger	*Panthera tigris*	LM	E	Indirect	0.5	0.3	0
3	Elephant	*Elephas maximus*	LM	E	Direct & indirect	0.9	0.6	5.8
4	Hoolock Gibbon	*Hylobates hoolock*	LM	E	Direct & indirect	0	1	0
5	Gaur	*Bos gaurus gaurus*	LM	V	Direct & indirect	9.4	0.7	24.3
6	Himalayan Black Bear	*Selenarctos thibetanus*	LM	V	Indirect	2.4	2.3	1
7	Dhole	*Cuon alpinus*	LM	V	Direct & indirect	0	0.3	7.8
8	Malayan Sun Bear	*Helarctos malayanus*	LM	DD	Direct	0.5	0.3	1
9	Barking Deer	*Muntiacus muntjak*	LM	LR	Direct & indirect	34.9	31.5	5.8
10	Jackal	*Canis aureus*	LM	LR	Direct & indirect	0.5	0.3	0
11	Leopard	*Panthera pardus*	LM	LR	Direct & indirect	0.5	0.3	6.8
12	Sambar	*Cervus unicolor*	LM	LR	Direct & indirect	17.5	16.1	16.5
13	Wild Boar	*Sus scrofa*	LM	LR	Direct & indirect	8.5	7.4	3.9
14	Rhesus Macaque	*Macaca mulatta*	LM	LR	Direct	0.5	0.3	0
15	Monkey	Species unknown	LM	-	Direct	0	0	1
16	Jungle Cat	*Felis chaus*	SMM	LR	Direct & indirect	0.9	0.6	0
17	Mongoose	*Herpestes* sp.	SMM	LR	Direct	0	0.3	5.8
18	Indian Porcupine	*Hystrix indica*	SMM	LR	Direct & indirect	0.5	1.9	1
19	Flying Squirrel	*Petaurista* sp.	SMM	LR	Direct	0.5	0.3	1
20	Indian Otter	*Lutra* sp.	SMM	LR	Direct	0.5	0.3	0
21	Chinese Pangolin	*Manis pentadactyla*	SMM	LR	Direct	0.5	0.3	0
22	Black Giant Squirrel	*Ratufa bicolor*	SMM	LR	Direct	0	0	2.9
23	Javan Mongoose	*Herpestes javanicus*	SMM	LR	Direct	0.5	0	0
24	Civet	Species unknown	SMM	-	Direct	0	0.3	0
25	Hare	Species unknown	SMM	-	Indirect	0.5	0.3	0
26	Squirrel	Species unknown	SMM	-	Direct	7.1	6.1	0
27	Cat	Species unknown	SMM	-	Indirect	0	0	3.9
28	Fishing Cat	Species unknown	SMM	-	Direct	0	0	6.8
29	Fruit Bat	Species unknown	SMM	-	Indirect	0	0	1
30	Bat	Species unknown	SM	-	Direct	0.5	0.3	1
31	Rat	Species unknown	SM	-	Direct	0.5	0.3	0
32	Mouse	Species unknown	SM	-	Indirect	0	0	1
33	Bamboo Rat	Species unknown	SM	-	Indirect	0	0	1.9

LM: Large mammal, SMM: Small-Medium Sized Mammal, SM: Small mammal
LR: Lower Risk, V: Vulnerable, E: Endangered, DD: Data deficient

similarity (Fig. 2).

An average of 72% (SE=8.6) large mammalian species reported for Bago was found in other regions of Myanmar. This includes the survey results of Tamanthi WLS, Rakhine, 1983 and 1996 and Bago 1983. The mean of 80% (SE=7.2) large mammals reported for Rakhine was comparable with other regions of Myanmar (including the 1983 survey by Sayer, in Rakhine).

When the regions were considered together for the differences in large mammals shared among them, the results were not statistically significant (Hc= 4.42, p>0.01). Considering specific regions, the differences across Bago and Rakhine were not significant (Hc= 1.104, p>0.01). A mean of only 61% (SE=5.0) of similar species of large mammals recorded in AKNP were reported for other regions of Myanmar; however, the differences between AKNP and Rakhine (Hc=3.57, p>0.01), and between Bago and AKNP (Hc= 1.87, p>0.01) were not significant.

Conservation Status of the large mammals reported for different regions

The percentage of all mammals, and endangered species (in relation to number of species recorded for each region) reported for Rakhine Yoma was high. The percentage of small mammals, vulnerable species and species under the data deficient category was greater in AKNP (Fig. 3). Bago

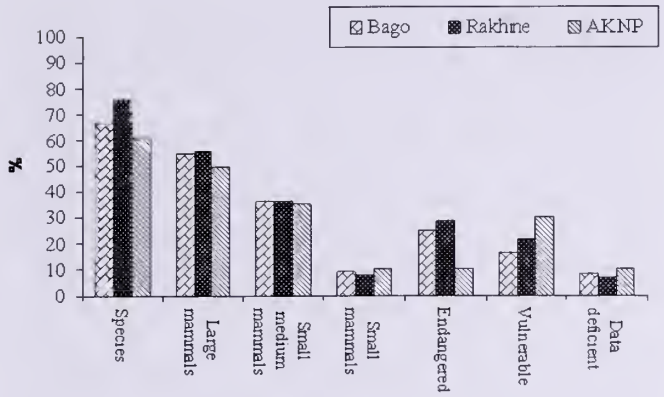

Fig. 3: Conservation status of mammals in different regions of Myanmar. Percentage values are plotted against all species, large mammals, small-medium sized mammals, small mammals and mammals under endangered, vulnerable, and data deficient categories of IUCN red list

contributed more only towards the percentage of small medium-sized mammals and its conservation status could have been equal to Rakhine in terms of the number of species of large mammals, endangered species and number of similar species shared with other regions (Fig. 3).

DISCUSSION

The current investigation results were comparable with that of earlier surveys carried out in Bago and Rakhine (FAO 1982; Sayer 1983) or in a region that has geographical and ecological similarities (Rabinowitz and Schaller 1995). The FAO (1982) survey reported about 17 species of large mammals in Bago with two species of Bear, Elephant, Gaur, Banteng, Eld's Deer (Thamin) and Tiger. Except for the Eld's Deer, Sumatran Rhino, Banteng and Serow, all other species were encountered by the current investigation.

Sayer (1983) reported 16 species of large mammals for Rakhine; except Banteng and the Sumatran Rhino, all other species reported by him have been recorded in the current investigation. A one-month survey carried out in the Tamanthi Wildlife Sanctuary of north Myanmar by Rabinowitz and Schaller (1995) reported 22 species of mammals for the region; of these, 17 were classified as large mammals and 5 species as small to medium sized mammals. Duckworth (1996) reported 30 species for the training and model forest of the Vientiane Forestry College in Laos. His survey reports more of small to medium size mammals with 7 similar species of large mammals occurring in the current investigation regions.

Sayer (1983) and FAO (1982) reported the Sumatran Rhino, Serow, Banteng and Phayre's Langur for both Bago and Rakhine, and FAO reported the Eld's Deer for Bago Yoma; no sighting of these species was reported in this investigation. It is also possible that some of these species have been completely eliminated or numbers have become so low that the sighting probability of these species has been reduced considerably. As mentioned by Rabinowitz and Schaller (1995), the level of human activities along with low law enforcement reported in some of the regions could indicate many large mammals following the path of the Sumatran Rhino towards extinction.

It is also expected that low density and endangered species could be wiped out from some of these regions (Rabinowitz and Schaller (1995). In the past, species considered as problem animals suffered through human-animal conflict. According to FAO 1982, a man-eating problem by tigers was reported in Bago Yoma and several tigers were shot to mitigate this issue. Like the tiger, each species suffers from different problems and their conservation status continues to be speculative. Sightings of tigers through indirect method (Table 2) in Bago and Rakhine Yomas have to be read with caution, as even with the past two decades of extensive efforts by National Park and Wildlife Conservation Division of Myanmar, no evidences of tigers anywhere in Myanmar has been discovered.

The percentage of total man-hours spent for collecting information was not the same across regions; it was maximum for Rakhine followed by Bago and the least for AKNP. This may have had some implication for the species reported for different regions, and it would have been possible to encounter

Table 3: Mammalian diversity and other associated parameters for the study area

		Bago		Rakhine		AKNP	
S.no	Parameters	All category	Only large mammals	All category	Only large mammals	All category	Only large mammals
1	No of species	22	13	25	15	20	10
2	Individuals	212	189	311	278	103	76
3	Dominance D	0.1895	0.2319	0.1635	0.1994	0.1166	0.1936
4	Shannon H	2.054	1.752	2.182	1.887	2.494	1.884
5	Equitability J	0.6644	0.683	0.6779	0.697	0.8324	0.8183

more species for AKNP, if more time had been spent collecting data. Tun (1997) reports species such as Banteng, Serow, Eld's Deer and Capped Langur for AKNP and noted that such species were not encountered during this investigation.

However, the information provided by Tun (1997) was not based on any specific surveys, but was a compilation of species or expected species reported for the region. The species list showed some uncertainty regarding species identification and a confusion of species between the Banteng and the Gaur was reported for the region (Tun 1997). Similarly, there may be some uncertainty for the species reported for AKNP. Another interesting point to be noted is that even with an equal or a slightly greater number of man-hours spent, surveys conducted for regions such as Tamanthi WLS, Rakhine (Sayer 1983) and Bago (FAO 1982) report more species of large mammals than AKNP.

Most of the animals (seen in the forest or visiting crop fields) were hunted, trapped and snared and a significant amount of meat sold in the local markets. Wire snares, simple but very efficient, and locally made traps were used. Porcupine, wild boar, barking deer, sambar, langurs, gaur, sun bears, jungle fowl, hornbills, pheasants, and a variety of other mammals and birds were hunted for meat and other uses. The most obvious indication of abundance of wildlife in Rakhine was the frequency with which game meat was sold at the roadside. Restaurants had abundant supplies of fresh, recently dried meat. Nearly all the forests of the region had been degraded as part of logging and taungya cultivation, but interestingly, this secondary vegetation proved to be the ideal habitat for wildlife.

In all these three regions, no evidence of strong and regular enforcement of law was noticed. A major threat to wildlife in the region surveyed would be the presence of professional hunters. Fish poisoning observed could affect both people and wildlife, being the removal of a valuable protein source from their habitats. Threatened large mammals such as the big cats, deer, gaur, and elephant continue to be in a critical state due to the illegal hunting of these species. In Tamanthi WLS of northern Myanmar, Rabinowitz and Schaller (1995) found people claiming ignorance of the fact that the area was protected under law and people did not understand what such protection meant other than not actively killing wildlife.

A similar trend could have been expected for the areas investigated. Threats to major species in Myanmar are from the escalating prices in the black market for animal products (Rao *et al.* 2005). For instance, illegal markets for tigers also offer scope for tiger prey species and other wildlife species (Bennett and Rao 2002; Rao *et al.* 2005). Recovery of most species of mammals is not possible due to the presence of permanent human settlements, roads and railway lines, cultivated lands, military and insurgence camps (Rao *et al.* 2005).

Current government budget allocation for protected areas may be less than that recommended for effective management (James *et al.* 1999). Legislation to protect both, mammals and their habitats is weak and difficult to enforce (Gutter 2001). Most of the regions need to evolve sensible wildlife management programs and protection, effective patrolling along the entry points of forests, and develop working or management plans, and stopping legal and illegal extraction of forests.

Since 2000, only one wildlife sanctuary has been established in this country, and only one legislation has been enacted (Aung 2007). Myanmar has 39% of paper parks (Braatz *et al.* 1992; Aung 2007) that lack site staff, law enforcement, delineated park boundaries and infrastructures. AKNP with its total area of 1,601 sq. km has only 0.08-forest staff/sq. km and the recently established Rakhine Yoma Wildlife Sanctuary for its 1,756 sq. km has only 0.01 staff/sq. km (Aung 2007). Major threats to the parks in this country during the last two decades have resulted from economic and land use decisions (Aung *et al.* 2004). Most of the landscapes have changed from old growth of forests to a patchwork of degraded secondary growth forest (Aung *et al.* 2004).

The annual net deforestation rate between 1989 and 2000 was 0.2% (Leimgruber *et al.* 2003), with some areas within the country experiencing a more severe rate of loss, which may exceed the global average (Lynam *et al.* 2006). However, although the current forest covers one third of the total land area of the country (Aung 2007), still has relatively low human population and impact (Sanderson *et al.* 2002). Myanmar includes the most extensive wild lands for large mammals in Asia (Leimgruber *et al.* 2003) and the protected area system has grown from less than 1% of the total land area in 1996 to a current level of 7% and there is a proposal to increase it to 10% (Rao *et al.* 2002). The species' richness along with the presence of endangered and vulnerable species, could still lead to all these regions investigated reaching the status of conservation importance. A collective and dynamic conservation approach to save these species will provide long-term conservation scope for these regions.

CONCLUSION

Geographically, Myanmar forms a land bridge between the mainland of continental Asia and Peninsular Malaysia; consequently, it encompasses varied ecosystems, diverse biological resources and geographical features. Myanmar still

has a low human population density. However, the population is increasing alongside numerous developmental activities. This change could cause increased pressure on the biodiversity of this little explored, species-rich region of Southeast Asia. Ironically, there are hardly any studies or even simple surveys of species distribution for most wildlife species. As and when any surveys are carried out on any focal species, it would be very useful to also document information on other species of wildlife in this region. The three regions surveyed represent a small portion of the major habitats in Myanmar and investigation was also restricted to providing some insights on the status of large mammals, and there was no scope for understanding the status of rodents, bats and the elusive, lesser-known, or other mammalian species not known to science. It could be assumed that understanding the status of major species of mammals and conservation of their environment will eventually help in understanding the status of lesser-known but highly diverse mammalian species. The current understanding of the status of mammals in these survey regions may also be motivating factors for future surveys in other regions of the country.

ACKNOWLEDGEMENTS

John, D. and Catherine, T. MacArthur Foundation, USA, and Rotterdam Zoo, the Netherlands, provided financial assistance to carry out the investigation. The Ministry of Forestry Myanmar (officials of both the Nature and Wildlife Conservation Division and Myanmar Timber Enterprises) and Members of Scientific Exploration Society, UK, provided active encouragement and support, and were keenly involved in the investigation. H.S. Suresh, Vijay, Sudhira, and Gururaj (Centre for Ecological Science - CES) provided valuable suggestions in data processing. A.J.T. Johnsingh (Nature Conservation Foundation), Renee M. Borges (CES), Sujata S. Iyengar, Tara Satyarata and Prof. Nicholas Polunin read through the earlier version of the manuscript and provided valuable inputs.

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NEW DESCRIPTIONS

RECORD OF TWO NEW SPECIES OF *APANTELES* FOERSTER (BRACONIDAE: MICROGASTRINAE) FROM CENTRAL INDIA

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Two new species *Apanteles neohyblaeae* and *A. lakhaensis* are described and illustrated. Specimens of *A. neohyblaeae* emerged from unidentified lepidopterous larvae on *Tamarindus indica*. Specimens of *A. lakhaensis* emerged from *Margaronia* sp., infesting *Casearia graveolens*. Further their affinities with the closely related species *A. hyblaeae* Wilkinson have also been discussed.

Key words: *Apanteles lakhaensis*, *Apanteles neohyblaeae*, Braconidae, Hymenoptera, Microgastrinae

INTRODUCTION

The microgastrine braconid wasps of genus *Apanteles* Foerster (Hymenoptera: Braconidae) include species which are economically very important since they parasitize various lepidopterous pests. Several *Apanteles* species have been reared from a large number of native lepidoptera and are undoubtedly important in regulating populations of many pest species (Varadarasan 1985; Mohan *et al.* 1992; Geetha Bai and Marimadaiah 2000; Pandey *et al.* 2004). In India, three *Apanteles* species, namely *A. hyblaeae*, *A. malevolus*, *A. subandinus*, have been imported as biocontrol agents of some major lepidopterous pests in agriculture and forestry (Singh 2004). Several workers including Wilkinson (1928), Bhatnagar (1948), Rao (1961), Nixon (1967), Sharma and Chatterjee (1970a, b), Sharma (1972, 1973a, b), Sumodan and Sevichan (1989) Kurhade and Nikam (1997), Sathe and Inamdar (1989), Sathe and Ingawale (1995), and Sumodan and Narendran (1990) have published research papers on the systematics of Indian species of *Apanteles*. Inspite of relatively good knowledge of braconid fauna from India, not much work has been carried out from Central India. In the present paper, two new species *Apanteles neohyblaeae* and *A. lakhaensis* are being recorded as larval parasitoids of lepidopterous insect pests, infesting forest tree species. The new species are being illustrated and described in detail.

MATERIAL AND METHODS

Systematic survey of various forests and agro-forest areas of Chhattisgarh and Maharashtra, India, was conducted for a collection of braconid parasitoids, and their host larvae of insect pests infesting forest tree species. Several larvae that were expected to be the common hosts of braconid parasitoids were collected from dense canopy of the forests. They were brought to the laboratory and attempts were made to rear the collected larvae on their host plant leaves. From a few larvae, adult braconids emerged. These braconids were collected and identified. Morphological terminology especially that of wing vein nomenclature follows that of modified Comstock-Needham system (Wilkinson 1928; Eady 1968) Figures were drawn with the help of camera lucida, attached to a stereoscopic trinocular microscope and measurements were taken by using an ocular micrometer.

Abbreviations used: OOL – Ocello-ocular line (distance from the outer edge of a lateral ocellus to the compound eye); POL – post-ocellar line (distance between the inner edges of the two lateral ocelli); AOL – anterior-ocellar line (distance between the inner edge of anterior and lateral ocellus); ØOD – diameter of an ocellus.

Apanteles neohyblaeae sp. nov.

(Fig. 1a-f)

Female: Body length 2.51 mm (excluding ovipositor and antenna); forewing length 2.4 mm; antenna length 3 mm.

Colour: Ground colour of the body largely reddish black; except legs largely reddish yellow; antenna, apical tip of hind femur, hind tibia at apical one third and hind tarsal segments largely, all coxae and ovipositor sheath reddish brown. The wing veins are light brown. The mandibles, palpi and tibial spur pale. First tergite dark brown while succeeding tergites are tumescent and reddish yellow.

Head: Head nearly as long as wide. Face finely punctate: OOL is half of POL. POL equal to ØOD, AOL is 1.2x POL. Malar space 1.7x base of mandible; antennae (Fig. 1a,b) filiform, with 16 flagellar segments and 1.2x longer than body.

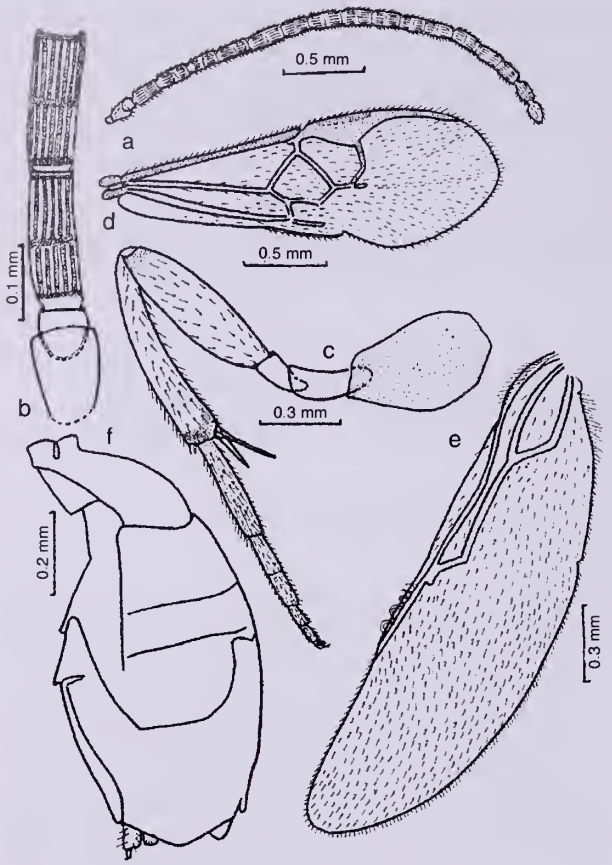

Fig. 1: a-f: *Apanteles neohyblaeae* sp. nov.: a. Antenna ♀, b. Antenna (enlarged) ♀, c. Hind leg ♀, d. Forewing ♀, e. Hind wing ♀, f. Metasoma ♀

Mesosoma: Mesonotum 1.1 mm long, rugose with regular punctations; forewings (Fig. 1d), 2.4 mm long, 0.9 mm broad, stigma 0.48 mm long and 0.18 mm wide, metacarp 0.51 mm, the 1st abscissa of the radial 0.19 mm, transverse cubital 0.10 mm, the apical portion of first abscissa of cubital 0.10 mm, recurrent vein 0.14 mm, pigmented portion of the 2nd abscissa of the cubital 0.09 mm, upper portion of basal vein 0.09 mm; hind wings (Fig. 1e) about 2.0 mm long, and 0.6 mm wide, vannal lobe of the hind wings sub-apically flattened with a few setae; hind legs (Fig. 1c), coxa finely, evenly punctate except outer face which is more or less bare, hind femur 0.63 mm long, 0.18 mm wide; tibia 0.75 mm long, 0.13 mm wide, basal joint of hind tarsus 0.38 mm long, longer tibial spur 0.24 mm long, shorter tibial spur 0.20 mm.

Metasoma: Metasoma (Fig. 1f) length 1.05 mm; first metasomal tergite more rugose in its apical half, 0.4 mm long, 0.3 mm apical width, 0.2 mm basal width. The second tergite is tumescent and bright and is bead-like sculptured along the central line. The ovipositor sheath 0.11 mm long, ovipositor 0.12 mm long.

Male: Same as female; except antenna (2.75 mm) is shorter than body (2.9 mm), the upper portion of the basal vein (0.05 mm) is shorter than pigmented portion of second abscissa of the cubital (0.06 mm), and the second tergite is not tumescent and bright as in female but is evenly punctate.

Holotype ♀ INDIA: Maharashtra, Ahmednagar (Kolhari), 19.ix.2007, emerged from unidentified lepidopterous larvae on *Tamarindus indica*; collected by Mohd. Yousuf; Paratype 3 ♀, 5 ♂, same data as for holotype.

Holotype ♀ and 1 ♂ paratype have been deposited at National Forest Insect Collection, Entomology Division, Forest Research Institute, Dehradun, India (Acc. No. 21895);

Remaining paratypes have been deposited at the Insect Collection Museum, Forest Entomology Division, Tropical Forest Research Institute, Jabalpur, India (Acc. No. 666).

Etymology: The new species, *A. neohyblaeae* is named so due to its close affinities with *A. hyblaeae*.

The new species, *A. neohyblaeae* is very close to *A. hyblaeae* Wilkinson, largely in having forewings with first abscissa of radial fairly straight, successively thicker below, well-marked from the transverse cubital, upper portion of basal vein shorter than apical portion of first abscissa of cubital, recurrent longer than transverse cubital, length of stigma shorter than metacarp. First metasomal tergite length 1.5x its apical width and slightly widening towards the apical end.

However, *A. neohyblaeae* differs from the *A. hyblaeae* in having transverse cubital equal to apical portion of first abscissa of cubital in *A. neohyblaeae* while in *A. hyblaeae* it is longer; upper portion of the basal vein equal to the pigmented portion of the second abscissa of the cubital while in *A. hyblaeae* the upper portion of the basal vein is longer than the pigmented portion of the second abscissa of the cubital. Hind legs with longer hind tibial spur three-fifth and shorter tibial spur about half the length of hind basitarsus in *A. neohyblaeae,* while longer hind tibial spur half and shorter tibial spur more than one third the length of hind basitarsus in *A. hyblaeae*. Further the two species differ in the first metasomal tergite in males. In *A. hyblaeae*, the first tergite narrowing towards the apex while in the new proposed species the tergite broadens at its apical end. The ovipositor sheath in the female of *A. hyblaeae* is as long as the basal joint of the hind tarsus while in the new species ovipositor sheath is about one-fourth as long as basal joint of the hind tarsus.

Apanteles lakhaensis sp. nov.

(Fig. 2a-f)

Female: Body length 2.8 mm (excluding ovipositor and antenna); forewing length 2.8 mm; antenna length 2.1 mm.

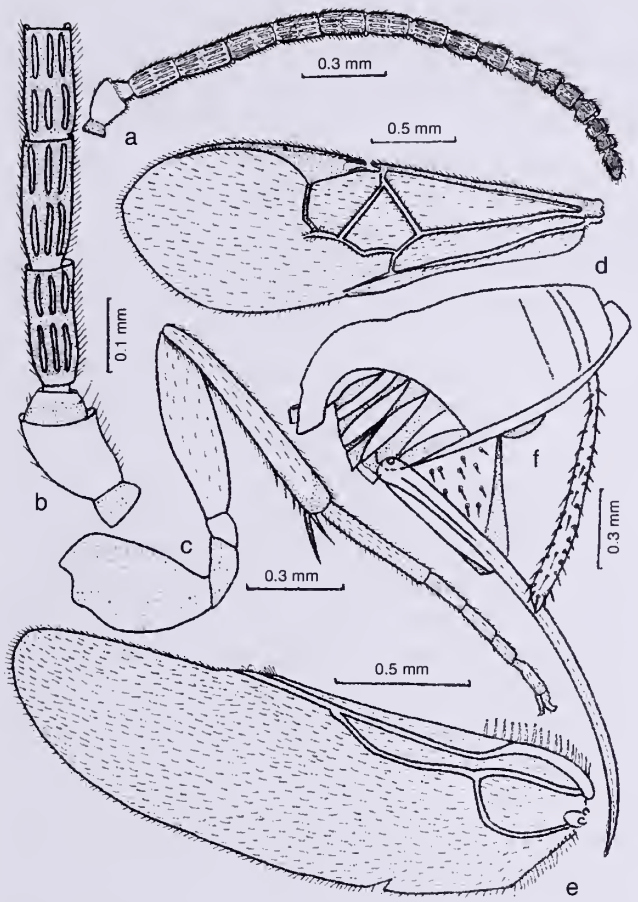

Fig 2: a-f: *Apanteles lakhaensis* sp. nov.: a . Antenna ♀, b. Antenna (enlarged) ♀, c. Hind leg ♀, d. Forewing ♀, e. Hind wing ♀, f. Metasoma ♀.

Colour: Ground colour of the body black; except head reddish black; legs brownish yellow; mandibles, antennae, coxa, apex of hind tibia and hind tarsi, stigma, metacarp, 1st abscissa of radial, transverse cubital, pigmented portion of the first abscissa of cubital light brown. Ovipositor sheath and stigma at the margins are brown; costal vein basally pale or apically light brown. Rest of the area of the forewing and hind wing hyaline; tibial spur pale.

Head: Face finely punctate, occiput with coarse indefinite punctation; OOL 3.3x POL, POL 0.75x shorter than AOL; OOL 2x ØOD; malar space 2.5x base of mandibles; antennae (2.1 mm) filiform (Fig. 2a,b), with 16 flagellar segments and is shorter than the body (2.8 mm).

Mesosoma: Mesonotum anteriorly with sparse and strong punctation and posteriorly having punctures, more widely separated and stronger; interspaces entirely smooth and highly polished and shiny; disc of the scutellum entirely smooth, highly polished and shining; propodeum basally largely rugose, apically virtually unsculptured, the areola not entirely devoid of indefinite punctures; carina of areola and costae strong. Fore wings (Fig. 2d) 2.8 mm long, 1.0 mm broad, stigma 0.58 mm long and 0.19 mm wide; metacarp 0.64 mm; the 1st abscissa of the radial 0.22 mm, successively thicker below, fairly well-marked from transverse cubital, transverse cubital 0.13 mm, the apical portion of the first abscissa of cubital 0.14 mm, recurrent vein 0.19 mm, pigmented portion of second abscissa of cubital 0.10 mm, upper portion of the basal vein 0.10 mm; hind wings (Fig. 2e) 2.20 mm long, 0.60 mm wide, vannal lobes of hind wings are sub-apically flattened with a few setae; hind legs (Fig. 2c) coxa is sparsely and evenly punctate, hind femur 0.61 mm long and 0.17 mm broad; hind tibia 0.78 mm long and 0.12 mm broad, hind basal tarsus 0.38 mm long, longer tibial spur 0.17 mm long, shorter tibial spur 0.11 mm long.

Metasoma: Metasoma (Fig. 2f) 1.20 mm long; first metasomal tergite 0.46 mm long, 0.30 mm apical width, 0.23 basal width; ovipositor sheath 0.80 mm long, uniformly hairy; ovipositor 1.2 mm long.

Male: Similar to female.

Holotype ♀ INDIA: Chhattisgarh, Raigarh (Lakha), 27.xii.2007, emerged from *Margaronia* sp, infesting *Casearia graveolens*, collected by Mohd. Yousuf; Paratype 2 ♀, 2 ♂, data same as holotype.

Holotype ♀ and 1♂ paratype have been deposited at the National Forest Insect Collection, Entomology Division, Forest Research Institute, Dehradun, India (Acc. No. 21896). Remaining paratypes have been deposited at the Insect Collection Museum, Forest Entomology Division, Tropical Forest Research Institute, Jabalpur, India (Acc. No. 665).

Etymology: The new species is named after the place of its collection, Lakha in Raigarh district, Chhattisgarh.

The new species, *A. lakhaensis* is also very close to *A. hyblaeae* Wilkinson largely in body characters. In the forewings first abscissa of radial is just longer than breadth of the stigma, fairly straight, successively thicker below, well-marked from the transverse cubital which is nearly equal to or just longer than the apical portion of the first abscissa of the cubital, as in *A. hyblaeae*.

However, it differs from the latter in having forewings with the length of the upper portion of the basal vein equal to the pigmented portion of the second abscissa of the cubital while in *A. hyblaeae* the upper portion of the basal vein is longer than the pigmented portion of the second abscissa of the cubital. Ovipositor sheath is two times longer than the basal joint of the hind tarsus in *A. lakhaensis* while in *A. hyblaeae*, the ovipositor sheath is equal to the length of the basal joint of the hind tarsus.

The two new species are also largely close to each other. Yet they differ from each other in having antenna longer than body in *A. neohyblaeae*, while in *A. lakhaensis* length of the antenna is shorter than body length. In *A. neohyblaeae* breadth

of stigma is more than the length of the recurrent while in *A. lakhaensis* width of stigma is equal to recurrent. The metasoma is shorter than mesosoma in *A. neohyblaeae* but longer in *A. lakhaensis*. The ovipositor and ovipositor sheath are very short in *A. neohyblaeae*, but very long in *A. lakhaensis*.

Apanteles hyblaeae Wilkinson, *Apanteles neohyblaeae* sp. nov. and *Apanteles lakhaensis* sp. nov. are closely related species; but these three species can easily be distinguished by the following key characters:

1. Fore wings with transverse cubital vein equal or shorter to apical portion of first abscissa of cubital vein; upper portion of basal vein is equal to pigmented portion of the second abscissa of the cubital vein; hind legs with longer tibial spur not half of basitarsus; length of ovipositor sheath not as above 2

— Fore wings with transverse cubital vein longer than apical portion of first abscissa of cubital vein; upper portion of basal vein is longer than the pigmented portion of the second abscissa of the cubital vein; hind legs with longer tibial spur half of basitarsus; ovipositor sheath about as long as hind basitarsus ..... *Apanteles hyblaeae* Wilkinson

2. Antennae longer than body; fore wings with transverse cubital vein equal to the apical portion of first abscissa of cubital vein; breadth of stigma more than the recurrent vein; ovipositor sheath about one-fourth as long as hind basitarsus ..... *Apanteles neohyblaeae* sp. nov.

— Antennae shorter than body; fore wings with transverse cubital vein shorter to the apical portion of first abscissa of cubital vein; breadth of stigma equal to the recurrent vein; ovipositor sheath two times as long as long as hind basitarsus ..... *Apanteles lakhaensis* sp. nov.

ACKNOWLEDGEMENTS

We are extremely thankful to Dr. A.K. Mandal, Director, TFRI, Jabalpur, and Dr. K.C. Joshi, Group Coordinator Research and Head, Forest Entomology Division, TFRI, Jabalpur, for providing necessary facilities and encouragement. Financial support from the Council of Scientific and Industrial Research, New Delhi (CSIR Project No. 37(1296) / 07/ EMR II) is also acknowledged.

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MISCELLANEOUS NOTES

1. THREATS TO FORAGING HABITAT OF INDIAN COURSER *CURSORIUS COROMANDELICUS* IN ABDASA TALUKA, KACHCHH, GUJARAT, INDIA

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Introduction

The Indian Courser *Cursorius coromandelicus* is a resident species of arid and semi-arid areas of the Indian subcontinent. It is quite common but rather patchily distributed in its distribution range. It is also partly nomadic and locally migratory. It generally inhabits wastelands and fallow land with scattered scrub, ploughed fields and village grazing grounds of dry stony plains and Deccan plateau. It avoids areas of heavy rainfall as well as pure desert (Ali and Ripley 1998). It is not found on the coast. This species has mostly been recorded during birding activities in India. It has not received any serious attention in terms of ecological studies. Globalisation and unplanned developmental activities have also affected the occurrence of the Indian Courser in some parts of the country. The population of the Indian Courser is declining at an alarming rate in its natural habitat (Pande *et al.* 2003). In Haryana, it has now become a rare breeding resident in Sultanpur Bird Sanctuary. Once it was common and lived among the scrub and wasteland vegetation of the campus of the National Chemical Laboratory, Pune, India, in the 1960s, but now it is rarely sighted there (www.ncl-india.org). In Gujarat, once upon a time, the Indian Courser was very common in grasslands and fallow lands. But it seems to be disappearing from some of the areas where it was found (personal communications from well-known ornithologists, eminent naturalists and bird watchers of the state). Most of the area has been converted to human habitation and agricultural activity. During our study of ecological aspects of the Indian Courser at Abdasa taluka, we observed that the main foraging habitat of the Indian Courser consists of short and sparse grasslands and fallow lands. This natural habitat is destroyed in some areas and disturbed due to the movement of heavy vehicles and the development of industrial establishments.

Study Area

Abdasa taluka of Kachchh district in Gujarat, India, was selected as the study site. It is situated in the south-western province of Kachchh. The area is of the arid and semi-arid type. In summer the temperature reaches 40-45 °C, and in winter it sometimes goes below 5 °C. Most of the area is wasteland or agricultural land. It falls under ecological zone 5A/DS 4 (Dry Grassland), with few scattered patches of 5A/DS 2 (Dry Savannah) (Champion and Seth 1968). One of the significant grasslands of Gujarat state is also within this area, the Naliya Grassland. The grassland is dominated by grass species such as *Cymbopogon*, *Aristida* and *Dichanthium*. *Acacia*, *Zizyphus*, and *Prosopis* are the major shrub/tree species (Meena *et al.* 2005). The major habitats in the area include grasslands, scrub lands, open lands, and permanent and temporary water bodies. However, some patches of dense *Prosopis* and planted shrub cover also exist.

Methodology

Data collection was carried out during regular field visits to the study area. Ten fixed length line transects were laid. The length of each transect was 1 km, and its width was 50 m on each side (total width 100 m) in all microhabitats. The transects were thoroughly surveyed from 0600 hrs to 1030 hrs and from 1600 hrs to 1830 hrs during May 2007-August 2008, covering all the three distinct seasons. Encounter rate was calculated using standard method.

Results

The maximum decrease in the Indian Courser encounter rate was observed in the saline grassland of Jakhau village. The maximum encounter rate of the species was recorded in November 2007 and the minimum in June 2007 in transect no. 1 (Fig. 1). But after March 2008, not a single bird was recorded in the transect and nearby areas. The same situation prevailed in transect no. 2 and 3 (Fig. 1), where the highest encounter rate of the species was recorded in July 2007 and of the lowest in February 2008 respectively.

The encounter rate declined in Naliya grassland too. The affected area was more than 0.1 sq. km; the actual area could not be measured because only one transect passed through this area (Fig. 1). From March 2008 onwards, plantation of trees was carried out in some fine grasslands in Naliya (Vinghaber). Due to this plantation activity, sighting of the Indian Courser became uncommon in this area (Fig. 2).

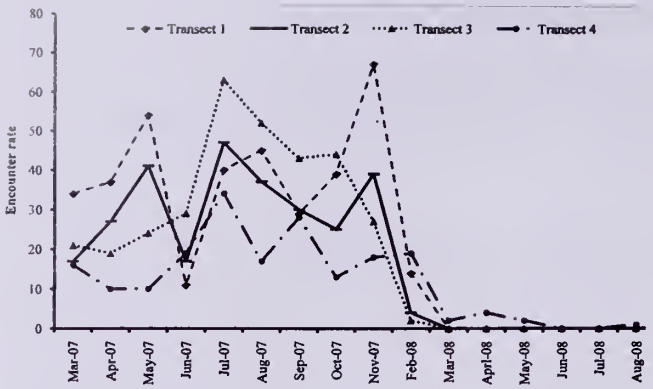

Fig. 1: Month-wise decrease in Indian Courser encounter rate in transects

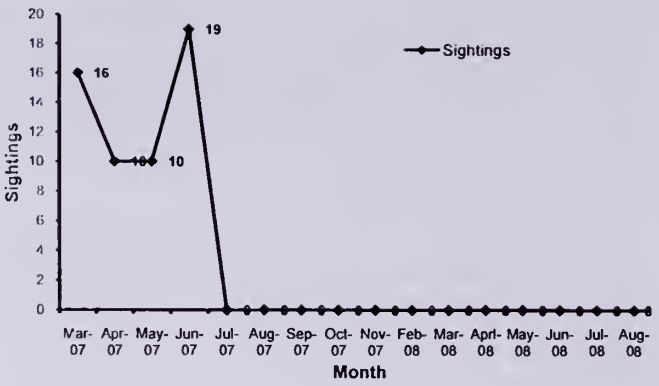

Fig. 2: Month-wise sighting of Indian Courser in area under plantation

Discussion

The Indian Courser density seems to fluctuate in some areas of the taluka as the species is nomadic and locally migratory. But in the grasslands of Abdasa taluka, the species gives the impression of having disappeared. The most affected foraging habitat was in transect nos 1, 2 and 3 (Fig. 1). These transects cover the saline grassland of Jakhau village. The study area is in close proximity to the Gulf of Kachchh, and thus the area is also interspersed with saline grassland habitat. Sudden changes in the encounter rate were observed due to the construction of windmills and the movement of vehicles in the area. The construction of windmills has totally destroyed the natural saline grassland. Earlier the species were recorded in good numbers, but due to haphazard construction of windmills, the habitat of the Indian Courser has been destroyed. The area was disturbed to make better roads for heavy vehicles to transport the windmill parts. The total area covered by transects during the present study was 0.3 sq. km in the saline grassland habitat of Abdasa taluka, However, the total extent of the affected area is more than 2 sq. km. The Indian Courser was also recorded outside the fixed width transect but were not considered for the data analysis. It is now an uncommon species in the entire study area.

The Indian Courser mainly utilizes the uncultivated fallow land, but at the time of cultivation, the fallow land becomes futile for the species (Indian Courser). The intense agricultural activity carried on in Kachchh is due to a good monsoon for the last 3 years. Due to this agriculture activity, the natural grasslands of the study area are being encroached upon. With encroachment for growing crops, utilisation of these habitats by the Indian Courser decreased. This is clearly seen in transect no. 4 (Fig. 1). Earlier, this area was covered with short grasses, providing a very good habitat for the Indian Courser. This kind of situation can also be seen in some parts of Abdasa taluka. One more threat to the habitat of the Indian Courser is plantation activities in the natural grasslands of the taluka. The Indian Courser does not prefer habitats with big trees. Plantation activities of the Forest Department in the natural grassland have destroyed the natural habitat of the Indian Courser. It has totally disappeared from this area (Fig. 2).

ACKNOWLEDGEMENTS

We are thankful to Shri. C.N. Pandey, IFS, Director, GEER Foundation, for his generous support during the field studies. We are also thankful to Dr. Bharat Jethva for his continuous encouragement and guidance during the study. We thank Shri. Virag Vyas for critical assessment of the manuscript.

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2. SIGHTING OF ALBINO CHANGEABLE HAWK-EAGLE *NISAETUS LIMNAEETUS* IN SITAMATA WILDLIFE SANCTUARY IN SOUTH RAJASTHAN

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The southern part of Rajasthan has a forest cover of deciduous species that looks dry during summer. But riparian strips along banks of streams in valleys remain green even during summer, a clear contrast to the landscape. Dotted dry bamboo brakes are seen in this part, especially where soil depth is more than 0.30 m. The high density of forest cover of southern Rajasthan supports many species of raptors. The Changeable Hawk-Eagle *Nisaetus limnaeetus* is regularly seen in wooded areas of Udaipur, Rajsamand, Banswara, Sirohi, Pratapgarh, Dungarpur and Chittorgarh districts. Bhardwaj (2008) has sighted this species in Sitamata Sanctuary in Chittorgarh-Udaipur districts. Sharma (2007) and Tehsin (1982) have recorded this species in Phulwari and Gogunda areas of Udaipur district respectively.

During our surveys we found this species in Kumbhalgarh Sanctuary (Udaipur, Rajsamand and Pali districts), Pipal Khunt forest area of Banswara district, Vanjoi-ki-Nal and Bhichhiwara forest areas of Dungarpur district. It is also present in Dhariyawad forests of Pratapgarh district (pers. obs.). This hawk-eagle is also seen in Ramgarh Vishdhari Wildlife Sanctuary of Bundi district in the Hadoti zone of the state (P.S. Chundawat, Asst. Conservator of forests and Warden of Ramgarh Vishdhari Sanctuary, pers. comm. 2009). We regularly observed this species in Ramkunda, Tinsara, Kheela, Samoli, Khokhariya-ki-Nal, Torna and Nal Mokhi forests of Udaipur district. It is also present in the thick forest cover of Morus area of Sirohi district. This species is widely present in denser forest zone of the state.

On August 29, 2008, while roaming in the Teak *Tectona grandis* forest of Ambareti forest block of Aarampura *naka*, Dhariyawad Range in Sitamata Wildlife Sanctuary, at about 1100 hrs, we observed an albino Changeable Hawk-Eagle *Nisaetus limnaeetus* perched on a bough of a tall *Lannea coromandelica* tree (Fig. 1). The adult eagle was milky white in colour. Tip and base of its upper mandible was pinkish-white, but the culmen was light grayish. The lower mandible and eye-rims were pinkish-white and feet maize yellow. The talons were pale and eyes were dark red. Its crest was clearly visible from a distance.

During monsoon, i.e., July to September, the Sitamata Sanctuary is covered with dense foliage, and the tree crowns become dark. The albino hawk-eagle was distinctly visible against the dark green foliage of the forest. This situation is probably not good for a raptor as it is easily visible to its prey.

At the time of observation, the bird was looking quite healthy. It appears that, at present, the Hawk-eagle is not facing difficulty in getting sufficient food.

Albinism has been recorded in many bird species, e.g., Crows (Mahabal 1991; Abdulla 1997), Red-wattled Lapwing *Vanellus indicus* (Soni 1992), Little Grebe *Tachybaptus ruficollis* (Bharos 1996), Red-vented Bulbul *Pycnonotus cafer* (Soni 1992; Joshua 1996), Lesser Whistling Duck *Dendrocygna javanica* (Chatterjee 1995), Common Myna *Acridotheres tristis* (Jha 1994) and Large Grey Babbler

Fig. 1: Albino Changeable Hawk-Eagle *Nisaetus limnaeetus* in Sitamata Wildlife Sanctuary Rajasthan

Turdoides malcolmi (Sharma 2003). An albino Grey Francolin *Francolinus pondicerianus* was seen in 2005 by I.P.S. Matharu, Dy. Conservator of Forests, Bassi Wildlife Sanctuary, Chittorgarh district, Rajasthan (pers. comm. 2003). Presence of albinism in Changeable Hawk-Eagle is a new addition to birds, hence worth placing on records.

ACKNOWLEDGEMENTS

Thanks are due to the field staff of Sitamata Wildlife Sanctuary for providing help during study. Thanks are also due to Shri I.P.S. Matharu and P.S. Chundawat for providing information about avian fauna of Bassi and Ramgarh Vishdhari Sanctuaries respectively.

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3. PRECISE LOCALITY RECORDS OF *ERYX WHITAKERI* DAS, 1991 WITH NOTES ON SCALATION AND A COMMENT ON ITS COMMON NAME

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Das (1991) described a new erycine snake – *Eryx whitakeri* based on a holotype collected from Mangalore (Karnataka State, India) in 1990. In 1991, this species was known to occur along the south-western coast of India – in Kerala (Cannanore); Karnataka (Mangalore and Dakshin, Kannada district); Goa (Panjim beach) and southern Maharashtra fide Das (1991). Earlier, Khaire and Khaire (1986) had reported a hybrid – *Eryx conicus* x *Eryx johnii* from Maharashtra (Alibaug, Raigad district), which, based on scalation and photographs, was identified by Das (1991) as *Eryx whitakeri*. Thakur (1998) extended the range of this species to include the Sahyadri Range of the Western Ghats (Maharashtra) without mentioning any precise localities. Whitaker and Captain (2004) also recorded it from, "sea level to at least 625 m (2050 ft) along the Western Ghats in Karnataka, Kerala, Goa and Maharashtra", again without naming precise localities. We herein cite eight authenticated records of *Eryx whitakeri* from Maharashtra (Table 1) based on individuals that were examined by at least one of the authors, as well as notes on scalation of the species.

Although previously reported from Maharashtra, more fieldwork needs to be done to determine if indeed this species is found throughout Maharashtra, or it is limited to higher rainfall areas.

In referring to this species, we follow Whitaker and Captain (2004) who stated that although this species would probably be assigned to *Gongylophis* (as its morphological

Table 1: Precise locality records for *Eryx whitakeri* from Maharashtra, India (based on direct observations by the authors)

Locality	District	Coordinates	Annual rainfall* (mm)
Nasrapur	Pune	N 18°15", E 75°53"	700-1,000
Mulshi	Pune	N 18°31", E 73°31"	6,500
Lohagad fort	Pune	N 18°46", E 73°22"	2,000-3,000
Ambavne	Pune	N 18°12", E 73°45"	5,000-6,000
Lonavla	Pune	N 18°45", E 73°22"	4,000-5,000
Khandala	Pune	N 18°53" E 73° 21"	4,000-5,500
Kankavli	Sindhudurg	N 16°15"34.3, E 73°43"09.83	4,000-5,000
Amba Valley	Raigad	N 18°45.402, E 73°21.204	4,000-5,500

*Ref. Climate of Maharashtra state (1972) Govt. of India, Indian Meteorological Department (based on 50 years of data)

Table 2: Scalation data for Maharashtra specimens of *Eryx whitakeri*

	No. 1	No. 2	No. 3	Range *fide* Das
No. of midbody scale rows	51	51	52	50-54
Scale on head and tail	Weakly keeled	–	Weakly keeled	No keels (=smooth)
Ventrals	212	217	211	201-206
Subcaudals	21	21	22	8-25
Scales between eyes	9	9	9	8-9
Scales around eyes	L11, R12	L11, R10	12	10-11
Supralabials	14	L13, R14	L 13, R 12	13-14
Anal	tripartite	tripartite	–	tripartite
Snout-vent length	810	660	–	–
Tail	45	42	–	–
Sex	female	female	female	–

Specimen from Kankavli (no. 1), Lohagad fort (no. 2) and Ambavne (no. 3) compared with corresponding data *fide* Das (1991)

characters are closer to *Gongylophis conicus* than to *Eryx johnii*). It should nonetheless be retained in *Eryx* as no supportive data has been published to the contrary.

Scalation data of three of these specimens were recorded (Table 2). Deviations from values listed by Das (1991) were: scales around the eyes - specimen no. 1: 12 on the right side and specimen no. 3: 12 on both sides (10-11 *fide* Das); supralabials - specimen no. 3: 12 on the right side (13-14 *fide* Das); ventrals - specimen no. 1: 212, specimen no. 2: 217* and specimen no. 3: 211 (201-206 *fide* Das). [*Ventrals - specimen no. 2: 213 entire, v/s 214-217 broken up into 3-4 scales, similar in size to those of the tripartite anal]. Specimen 1 and 3 both had scales on the head and tail that were weakly, but distinctly obtusely keeled. Specimen 3 also had weakly keeled dorsal body scales. In his original description (Das 1991) states that there are 'no keels on the scales of the dorsal surface of body including forehead'.

E. whitakeri has been called Whitaker's Sand Boa [*sic*] by Das (1997) in a Checklist of Indian Reptiles and has subsequently mostly been referred to as such. Whitaker and Captain (2004) refer to this species as Whitaker's Boa [*sic*] without noting reasons for the change. Although common names are a subjective issue and one could argue that especially since some snake classifications recognize the Erycinae or even Erycidae, Das was technically justified in naming this snake "Whitaker's Sand Boa", readers unfamiliar with snake systematics might not understand that there was indeed a valid reason for Das to use the name he did. Even though calling this snake "Whitaker's Boa" could imply membership in the "true" boa group, Boinae, we prefer this common name. It may be noted that despite Das (1991) mentioning a juvenile female (ZSI 22152) collected from 'Panjim sea beach, 29 km west of Ponda, Goa' – a sandy area, all the specimens (including the aforementioned) have been found in areas of heavy rainfall. To users of common names, 'sand' boa suggests that this species inhabits arid or sandy areas and is a misnomer. The original common name implies nothing about habitat, but rather indicates that the species is a member of the genus of "sand boas" - as this name is used for all *Eryx* (*sensu lato*).

We opine that (when possible) a common name should aid lay people in identifying that species, be descriptive, or have some bearing to its environment and calling this snake a 'sand boa' (based on scientific classification) could mislead readers who use common names to infer that this species inhabits arid regions. As common names for Indian snakes have never been 'standardized', we leave it to readers to use whichever common name they prefer.

ACKNOWLEDGEMENTS

We thank G. Nanavre, S. Ghodke, A. Gama, Mr. Jadhav for showing us live *E. whitakeri* individuals; Captain J. D'silva for sharing habitat notes of specimens found in Goa and Dr. Swati P. Gole and Dr. Aparna Watve for kindly providing us with the rainfall data in Table 1.

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4. OCCURRENCE OF INDIAN PAINTED FROG *KALOULA TAPROBANICA* (FAMILY MICROHYLIDAE) AT ARNALA BEACH, MUMBAI, MAHARASHTRA

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On July 16, 2009, while walking near Arnala beach (19° 27' 07.32" N; 72° 44' 54.64" E), Virar, Mumbai, Maharashtra, we came across a small frog on a bark of *Casuarina equisetifolia*. Based on its coloration and morphological features, e.g., fingers enlarged into large and flattened discs, it was later identified as Indian Painted Frog *Kaloula taprobanica* (BNHS Reg. No. 5250).

This species belongs to Family Microhylidae. It is a medium-sized (adults < 6 cm) frog with snout flat, triangular, and balloon-like body with obscure or absent tympanum (Daniel 2002; Daniels 2005). This is one of the widely distributed but uncommon species of frog in many areas. It is reported from many places in Assam, West Bengal, Orissa, Bihar, Tamil Nadu, Karnataka, Kerala, Andhra Pradesh, Madhya Pradesh and Gujarat (Giri *et al.* 2001; Daniel 2002; Sivakumar *et al.* 2003; Daniels 2005; V. Giri pers. comm.). This species is found in rural, agricultural and forest area, including Western Ghats and are well adapted to live in highly urbanized areas also (Daniels 2005). Interestingly, it is found from sea-level to over 1,000 m above sea level (Daniels 2005). According to mentioned references this species was not reported from Maharashtra until recently, and thus deserves attention.

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5. OCCURRENCE OF EPIZOIC CIRRIPEDE, *CONCHODERMA VIRGATUM* (SPENGLER, 1790) ON *PENNELLA INSTRUCTA* WILSON INFECTED ON SAILFISH *ISTIOPHORUS PLATYPTERUS* CAUGHT FROM NORTH-WEST INDIAN EEZ

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Introduction

Indo-Pacific Sailfish *Istiophorus platypterus* (Shaw and Nodder 1792) belonging to Family Istiophoridae is a primarily oceanic, epipelagic fish inhabiting the tropical and temperate waters of Pacific, Indian and Atlantic oceans. This fish constitutes a major bycatch component of tuna longline fishery in the Indian waters. The abundance of this species in the north-western Indian Exclusive Economic Zone (EEZ) is evident from the fact that an average catch rate of this species in the exploratory longlining was 39.42 kg/1000 hooks, constituting 15% of the total catch (Varghese *et al.* 2004). *Pennella instructa* Wilson (Syn. *Pennella zeylanica* Kirtisinghe) is a copepod parasite infecting many marine fishes, especially billfish, including swordfish, sailfish and marlin. In India, Devaraj and Bennet (1972) had described this species infested on sailfish, *I. platypterus* (Shaw and Nodder, 1792) and collected from the South-east and South-west coasts of India. During September 2006 survey voyage of *MFV Matsya Vrushti*, longline survey vessel of Fishery Survey of India operating from Mumbai Base, seventeen female specimens of *Pennella instructa* Wilson were collected from two sailfishes caught from 18-19 °N and 67-69 °E. All the

specimens collected were found to be with epizoic cirripede *Conchoderma virgatum* (Spengler, 1790) attached on it. *C. virgatum* Striped Goose Barnacle is a pelagic cirripede found in all tropical waters of the world, attached to nearly all larger forms of marine life, including parasitic copepods, turtles, sea snakes, sunfish, swordfish, humpback whales and sperm whales. In India, Daniel and Premkumar (1967) had reported the occurrence of *Conchoderma virgatum* on *Pennella* sp., parasitic on *Cypsilurus speculiger*; Natarajan and Nair (1970) on *Lernaeenicus hemiramphii* Kirtisinghe; Fernando and Ramamoorthy (1974) on a scyphozoan medusa and Lazarus and Sreenivasan (1980) reported its occurrence on *Pennella diodontis* Oken.

The present study was conducted during the September 2006 voyage of the longline survey vessel *MFV Matsya Vrushti* conducted along the north-western Indian EEZ, between 18-22 °N for tunas and allied resources in the oceanic waters using monofilament longline. Elongated parasites were observed along the dorsal fin base of two sailfish caught on September 15 and 18, 2006, with Fork lengths 154 cm and 180 cm respectively; the samples were brought to the shore laboratory for further analysis. The first fish was infested with eleven individuals of *P. instructa* Wilson while the second fish had six parasites attached to it just below the dorsal fin. Skin and muscular necrosis was observed around the area of attachment of the parasite. Removal of the parasites from the fish body was difficult as the cephalosome and neck were deeply buried in the flesh. Since the two specimens were damaged while trying to pull out the parasite, flesh was cut from the area of infestation to get the remaining parasites intact. After reaching the shore laboratory, each parasite was removed carefully by cutting the flesh and was identified as *P. instructa* based on the characters described by Devaraj and Bennet (1972). The parasites collected are stored in the museum of Fishery Survey of India, Head Quarters in Mumbai.

***Pennella instructa* Wilson** (Copepoda: Pennellidae)

The total length of the parasites was in the range of 8.1 to 14.8 cm. About 60% of the total length was embedded in the flesh of the host close to large blood vessels. Thick fibrous cyst formation was observed in the flesh of host around the parasite. The head and horns were found to be immersed in an area full of blood and inflammatory exudates. The parasite had bulbous cephalosome having two long unbranched projections or horns, which extend posteriorly, and parallel to the neck. These horns are antennae modified to antlers (Kabata 1979) and also closely resemble conventional fish tags. The flat portion of the cephalosome is partially covered with papillae. The cephalosome and neck are yellow and the trunk intensely keratinised and dark brown. The body extends from the host and terminates in dense beard or feather-like mat of simple lateral projections. Yellow coloured egg strings are straight and very long.

Although no visible effects were observed on the host except skin and muscular necrosis, the location of the parasite near large blood vessels may have disastrous effects on the host. The extreme host reaction to the infestation is evident from the formation of thick fibrous cyst around the parasite. Hogans *et al.* (1986) found that this copepod weakened the host by damaging the heart. Many young sailfishes are rendered prone to get killed, debilitated or perished due to predation because of this parasite. However, these parasites are reported to be harmless to humans if consumed along with fish.

***Conchoderma virgatum* (Spengler, 1790)**
(Cirripedia-Lepadomorpha)

In the present study, Striped Goose Barnacle, *Conchoderma virgatum* (Spengler, 1790) was found to be attached on the trunk of all the parasites collected. When the sailfishes were taken onboard, these cirripedes were in live condition, moving their flap like appendages through the mouthfield. Total number of association of the barnacle varied from 2-22 per parasite. The total length of the barnacle was in the range of 3.5 to 19.0 mm. The base stem (peduncle) and body (capitulum) are blended together without forming a distinct separation. The capitulum is white with brown striations. Six pairs of biramous cirriform legs were present in the trunk, which were dark brown. Caudal appendages were absent. Attachment to the parasite is made by means of a very adhesive cement-like substance. Natarajan and Nair (1970) had reported the absence of egg strings and puncturing of the substratum in addition to inflammation due to *Conchoderma virgatum* infestation on *Lernaeenicus hemiramphii*. But, in the present study, no visible effects of infestation were observed on *P. instructa* except inflammation on the place of attachment and, even the copepod with 22 barnacles attached to it was found to be bearing the egg string.

This is the first report of infestation of *Pennella instructa* on sailfish from the north-west coast of India and is the first reported instance of occurrence of *Conchoderma virgatum* on *Pennella instructa* parasatized on sailfish in the Indian waters. Devaraj and Bennet (1972) have described the characters of this parasite infested on sailfish collected along the South-east and South-west coasts of India. In the present study, all the parasites collected had *Conchoderma virgatum* attached to it.

Recently, many parasites, including *Pennella instructa*

had gained much importance for using as biological tags to discriminate billfishes with different histories of movement and thereby stock identification. Fish may become infested by parasites in specific geographic regions during their life history and therefore "marking" them with an identifiable natural tag indicating the habitat occupied previously, and which may allow it to be distinguished from other fish from different origin. Thus, investigation of the parasite assemblage of fish may provide information about their life cycle, movements and stock identity (MacKenzie and Abaunza 1998). The use of parasites as natural tags offers several advantages over artificial tags. Fish only need to be caught once, thus maximizing sample sizes, whereas when fish is tagged artificially, only a small proportion of these tagged fish may be recaptured, recaptures may be spatially biased, and may affect the behaviour of fish. Parasites sampled, can provide preliminary information to aid the design of complex population sampling and tagging studies. Further, parasites as biological tags can be used for studies of delicate and deepwater species, including crustaceans, which may shed their artificial tags when they moult (Pawson and Ellis 2005). The significant difference between *P. instructa* and artificial tag anchors is that *P. instructa* develops the anchor fully when it has reached its final destination at a food source in the host (Wilson 1917) while the artificial tag anchors, by contrast, are preformed and therefore increase the relative area of tissue damage during penetration, weakening the attachment strength. Development of smart tags, which mimics the mode of attachment of *P. instructa* to the host fish, will definitely solve many of the adverse effects of artificial tags on tagged fish in future. *P. instructa* is an ideal biological tag for billfishes as this parasite is comparatively long living, can easily be detected and identified, and is very difficult to remove from the host body. Speare (1995) used several parasites including *P. instructa* to distinguish stocks of sailfish in Queensland (Australia) waters. Similar studies can be employed to identify the sailfish stocks occurring in the Indian waters, as the sailfish constitute a major component of the longline fishery in the Indian waters. Similarly, possibility of using *P. instructa* as a biological tag to trace the origin of fish in the catches of vessels conducting transoceanic fishing is to be investigated. The impact of infestation by *P. instructa* on the sailfish needs further investigation to estimate the extent of damage, incapacitation and mortality caused on the sailfish due to parasitism.

ACKNOWLEDGEMENTS

We would like to thank the Captain and crew members of the vessel *MFV M. Vrushti* for assisting in sample collection. Assistance rendered by Shri Vishal Bhanji in data collection also is acknowledged.

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6. ON A RECORD OF *AMPHILOPHUS TRIMACULATUM* (GÜNTHER) (TELEOSTEI : PERCIFORMES: CICHLIDAE) IN THE NATURAL WATERS OF TAMIL NADU, INDIA

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In India, most species of native freshwater fish have evolved under riparian or shallow marsh-like conditions as there have been very few natural tropical lakes. As a result, the Indian fish fauna lacks the phenomenal diversity of lentic (stagnant water) fishs, especially of cichlids, that Africa and South America boast of (Lowe-McConnell 1987). The three native cichlids (chromides) are *Etroplus maculatus* – the smallest and most widespread of chromides occurring locally in streams, rivers and marshes, *Etroplus suratensis* – a brackish water-estuarine species and *Etroplus canarensis* – an endemic to the streams of the Western Ghats. The last is a rare chromide and very little published information exists of its habits (Menon *et al.* 1993).

Until now only one genus of African Tilapia (*Oreochromis*) was known amongst the introduced fish in India. *Oreochromis mossambica*, a cichlid, which was first introduced in 1952 as a food fish has practically colonized all freshwater and brackish water habitats in India (Daniels 2002).

Recently, a cichlid of the genus *Amphilophus* belonging to a diverse group of South American cichlids formerly classified as *Cichlasoma* (Kullander, 1983) has been recorded for the first time through collections from Rettai Eri, a wetland in Chennai. The specimens collected are very similar to *Amphilophus trimaculatum*, popularly known as the 'trimac cichlid' or 'red-eye cichlid'. The native range of *A. trimaculatum* is Laguna Coyuca, Mexico to the Río Lempa, El Salvador (Nico 2009). Non-native distribution has also been recorded from Florida (Shafland 1976). The individuals collected in Chennai differ slightly in having neon green spots on the base of each scale (Fig. 1). These fish are traded as aquarium pets under the trade name 'Flowerhorn', keenly sought by the practitioners of Feng-Shui.

The Flowerhorn cichlid is believed to be a product of hybridisation between different species of South American cichlids classified under the genera *Cichlasoma* and *Amphilophus*, or it is also plausible that the trimac cichlid is injected with hormones or selectively bred to enhance its colour and body shape. The neon green scales in the specimens from Rettai Eri could be attributed to either of the above. These specimens also have bright red eyes and a spot on the nuchal region characteristic of *A. trimaculatum*; a characteristic also clearly noticeable in juvenile specimens (Fig. 2).

The Flowerhorn is likely to emerge as a greater invasive than the Tilapia. The Tilapia is an omnivore but the Flowerhorn is a predacious fish that eats smaller fish. Under aquarium conditions these fishes are highly predacious and aggressive and have been observed to devour any small fish introduced into the aquarium. *A. trimaculatum* is known to grow to more than 36 cm in length (Nico 2009), and even a

Fig. 1: Adult Flowerhorn collected from Rettai Eri, Chennai

Fig. 2: Juvenile Flowerhorn collected from Rettai Eri, Chennai

well-grown Tilapia may not stand a chance against this marauder.

The emergence of Flowerhorn in natural waters is a consequence of unregulated aquarium trade in the country. This fish may have escaped during floods from the ornamental fish farms around Rettai Eri in Chennai, where breeding of ornamental fish is unregulated. Apart from developing appropriate norms to oversee aquarium fish trade, we need to monitor issues such as accidental or deliberate release of exotic fish species into our waters. If these issues continue to remain unnoticed, our waters will soon emerge as breeding grounds of invasive fish that will eventually reduce the native freshwater fish diversity.

ACKNOWLEDGEMENT

We thank Mr. Venkat, Dolphin Aquarium, Chennai for his help in the collection of samples.

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7. *IXORA CHINENSIS* LAM.: A NEW HOST PLANT FOR COMMON SILVERLINE *SPINDASIS VULCANUS* FABRICIUS, (LEPIDOPTERA: LYCAENIDAE) FROM WEST BENGAL

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Common Silverline *Spindasis vulcanus* Fabricius (Family Lycaenidae) is one of the most widespread and common butterfly of the Indian region. The butterfly is omnipresent ranging from sea level to the crest-lines of mountain ranges, and from scrub to secondary evergreen forests, but it occurs primarily in open areas (Kunte 2000). The adult butterfly feeds on nectar of a wide variety of plants. The recorded larval food plants are *Allophylus cobbe* (Sapindaceae), *Cadaba fruticosa* (Capparaceae), *Canthium coromandelicum* (Rubiaceae), *Clerodendrum indicum* (Verbenaceae), *Zizyphus mauritiana* and *Zizyphus rugosa* (Rhamnaceae) (Wynter-Blyth 1957; Kehimkar 2008).

A new host plant has been recorded by the authors for Common Silverline in the campus of Indian Botanic Garden. The Garden, previously known as the Royal Botanic Garden, is located on the western bank of the Hooghly river in Howrah, opposite Kolkata city in West Bengal. Several caterpillars of the butterfly were found on the mature leaves of Chinese Ixora (Torch Tree *Ixora chinensis* Lam., Family Rubiaceae). However, unlike the previous reports of the peculiar style of feeding of the caterpillar from the lower surface of the leaves of their host plants, leaving the upper cuticle intact and shrivelled (Kunte 2000), a few of them in the present case have been found to eat from the upper surface of *Ixora chinensis* leaves. All the larvae were attended by ants.

Ixora chinensis is a dwarf species of tropical evergreen plants of the genus *Ixora* (Family Rubiaceae), attaining a height of 1.5 m. A native of China, distribution of *I. chinensis* now extends from southern China to India. At present a large number of cultivars of *Ixora chinensis* are being cultivated throughout the tropics for their ornamental value characterized by long lasting flowers and attractive shiny leaves (Chakraberty and Jain 1984; Bose *et al.* 1991). The species serving as the host plant for Common Silverline in the present study area is a small erect shrub, attaining a height of 0.97 m with scarlet flowers.

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8. FIRST RECORD OF AN EXOTIC BUTTERFLY LEOPARD LACEWING *CETHOSIA CYANE* FROM THE ANDAMANS

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The Red Lacewing *Cethosia biblis* (Lepidoptera: Rhopalocera) is represented by two subspecies one each in the Andaman and Nicobar islands: Andaman Lacewing *C.b. andamana* and Nicobar Lacewing *C.b. nicobarica*, respectively (Bingham 1905; Evans 1932; Ferrar 1951). After the Tsunami of December 26, 2004, we observed a Lacewing which appeared similar to *Cethosia biblis*.

Later, the immature stages of the butterfly were reared and were found to be different from that of *Cethosia biblis* described by Igarashi and Fukuda (1997). The emerged adult was identified as *C. cyane*, a species not reported from Andamans by earlier workers (Bingham 1905; Evans 1932; Ferrar 1951; Khatri 1991).

The Leopard Lacewing is not restricted to just South Andaman, but has spread to the Middle and North Andaman up to Diglipur. The native butterfly *Cethosia biblis* seems to be failing to compete with the exotic butterfly as it has not been seen in Andamans for sometime now. This is a matter of serious concern.

The Leopard Lacewing is a common butterfly flying throughout the Andamans. Its food plant *Passiflora foetida* is an introduced plant, which has spread to the South, Middle and North Andaman from Port Blair up to Diglipur.

ACKNOWLEDGEMENT

The authors are grateful to Mrs. Samhita Acharya for typing the manuscript.

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9. BIOLOGY OF NILGIRI TIGER *PARANTICA NILGIRIENSIS* (MOORE 1877): AN ENDEMIC BUTTERFLY OF THE WESTERN GHATS OF SOUTHERN INDIA

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Introduction

Parantica nilgiriensis (Moore 1877) is a near-threatened (IUCN 2010) butterfly endemic to the high altitudes of the Western Ghats of southern India, belonging to the Family Nymphalidae and Subfamily Danainae. It is restricted to the shola forests, south of Nilgiri Hills, in the temperate zones of the mountains, above 1,500 m, though the species occasionally shows up in home gardens and open country to visit flowering plants. It rarely flies as low as 1,000 m (Larsen 1987). Though Wynter-Blyth (1957) and Kehimkar (2009) mention it as a common species, it has seen a rapid decline in the density of its population over the last few decades, owing to rapid destruction of its habitats, mostly due to tea-monocultures in the mountain ranges.

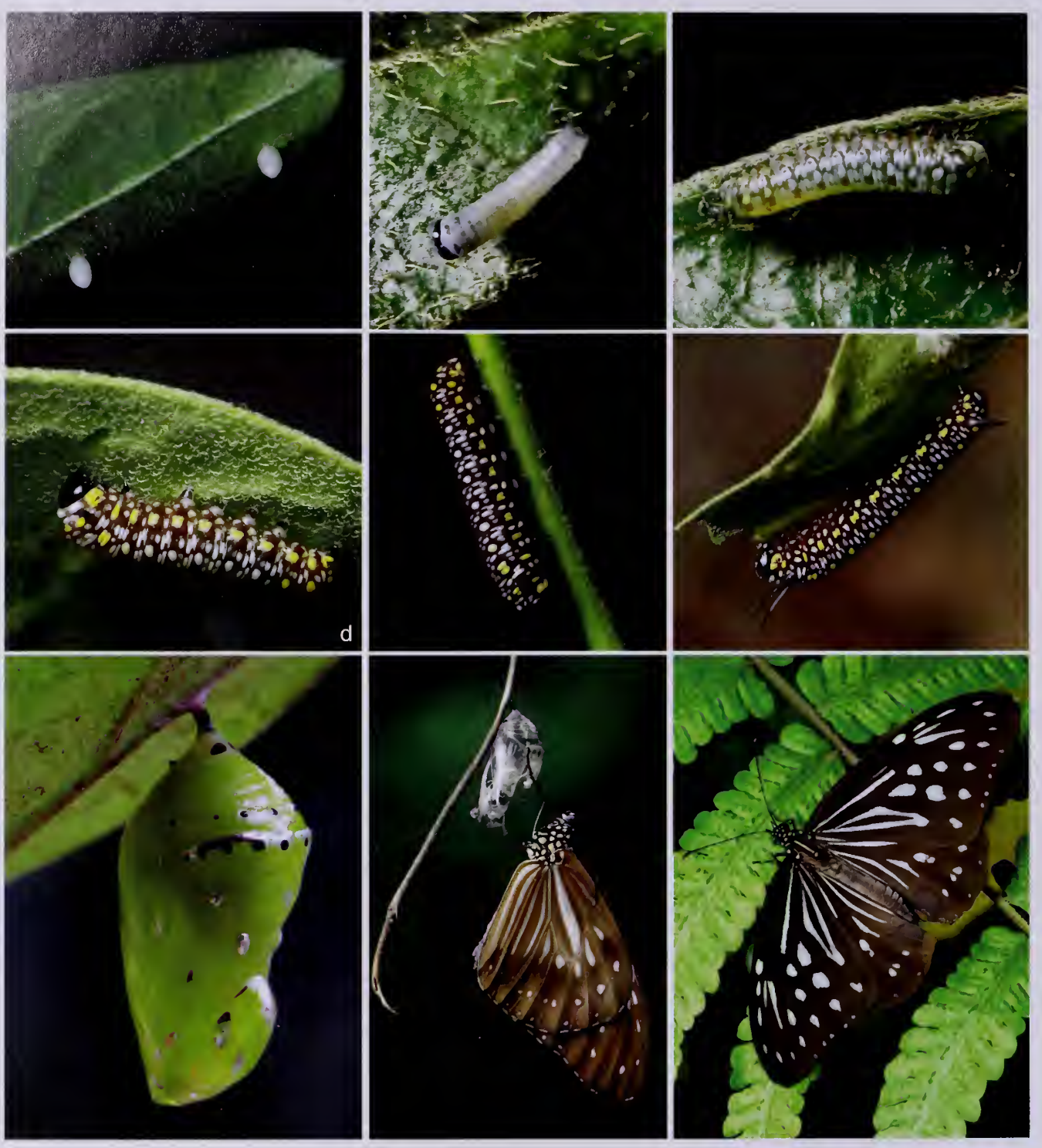

Fig. 1 (a-i): *Parantica nilgiriensis* (Moore 1877): a. Egg-laying behaviour; b. First Instar; c. Second Instar; d & e. Fourth and Fifth Instars; f. Fisth Instar; g. Pupa; h. Adult underside; i. Adult upperside

Even though most workers mention the adult behaviour, distribution patterns and population statistics, no work has so far been published on the biology of the immature stages of the species. There is no reliable literature about the larval host plants of the butterfly either. This paper intends to fill this gap to a satisfactory level, though there is still scope for further studies on adult breeding behaviour and population trends.

Species that closely resemble *P. nilgiriensis* are *P. fumata* (Butler), a Sri Lankan endemic and *P. aglea* (Stoll), a common species of low elevations of India, Sri Lanka, and other South-East Asian countries.

Eggs were collected, after observing an adult female laying eggs on a creeper, from a cultivated land near a degraded shola forest close to Udumbanchola in Idukki district of Kerala, at about 1,500 m altitude. The eggs were reared in a controlled home-lab, judiciously trying various probable host plants, chosen on the basis of host plant preferences of related species belonging to *Parantica* genus. Every instar of the caterpillars was observed and documented photographically, giving special attention to larval behaviour and morphological transitions. Adults hatched from the pupae were released in suitable habitats after taking photographs.

Host Plants: *Tylophora tenuis* and *T. indica*. *P. nilgiriensis* does not seem to feed on *Calotropis* sp. which its close cousin *P. aglea* feeds on.

Egg-laying behaviour: The adult female lays several eggs on the underside of a leaf in a session, laid singly, at times two or more eggs on a single leaf, always maintaining some distance between individual eggs (Fig. 1a).

Eggs: Eggs are white, shiny, dome-shaped and ribbed.

Larva: Eggs hatch on the fourth or fifth day.

First instar is a small, pearly white caterpillar with a prominent black head and dark grey legs. It has small paired tubercles on the second and twelfth segments, which are precursors of future tentacles (Fig. 1b).

Second instar is larger and has a greenish brown ground colour along with white, oval and round spots similar to that is seen on the final instar (Fig. 1c). There are four longitudinal rows of round spots – two dorsal and two lateral on each side. All the spots on the lateral rows, and the first two spots of the last three segments on the dorsal row are yellow. There is a pair of small tentacles on the second segment and a pair of tubercles on the twelfth segment.

Third and fourth instars are similar to the second instar except that the caterpillar grows in length and thickness, the tentacles elongate and the white spots gradually turn yellow on all segments (Figs 1d & e).

Fifth instar is about 6-7 cm long with long, thin, black tentacles on the second and twelfth segments, the first pair being longer. In this stage all the white spots of the four longitudinal rows are yellow, with dark brown ground colour (Fig. 1f). The other smaller spots and short streaks remain grayish white.

Larval behaviour: The first and second instars show a strange behaviour of 'Silk Diving' – the larva when alarmed simply drops down, and hangs on its own silk thread – a protective, predator-avoidance strategy observed in some Nymphalids, but unknown in Danaids. As the larvae mature, they seldom show this behaviour. (No nipping of the midrib was observed before feeding).

Pupa: Pupation occurs after 14-15 days. Pupa is green with shining silvery and black spots. It hangs freely from the underside of a leaf or twig (Fig. 1g), appearing very similar to that of Plain Tiger *Danaus chrysippus*. The pupal stage lasts for 11-12 days. The pupa begins to show the pattern of the underlying wings on the eve of eclosion. It turns very dark, nearly black, on the night before hatching.

Adult: Wingspan – 80-90 mm. Both male and female are dull brownish-black with dirty white markings above (Figs 1h & i). The streaks are narrower and the spots smaller than those of *P. aglea* and *Tirumala limniace*. The markings are much less extensive than the background. Cells are dark with a pale streak. Male has a patch of scent scales on the hind wing (Wynter-Blyth 1957).

Adult behaviour: The flight is rapid, low and erratic for a Danaid, giving the impression that it may not be a protected species. It is often seen in numbers on flowering trees or occasionally on Lantana in clearings in sholas. From time to time it is also met with sipping moisture from water seepages in vertical banks in the forest or along clear brooks, something that may also be observed in other montane butterflies (Larsen 1987).

ACKNOWLEDGEMENTS

I acknowledge the field support provided by Dr. Biju C.R. and Mr. Pradeep Menon during our field trips to the highlands and sholas. I thank Ms. Sandhya Krishnan for providing all support and help while rearing the caterpillars in the home-lab. The moral support given by Dr. George Mathew, Isaac Kehimkar, and Krishnamegh Kunte, along with other members of the Butterfly India Group, was of immense importance.

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10. COMPARATIVE STUDY ON THE BIOLOGY OF *EUDRILUS EUGENIAE* (KINBERG) AND *EISENIA FETIDA* (SAVIGNY) UNDER LABORATORY CONDITIONS

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Introduction

Many species on our planet, such as bacteria, fungi, protozoa, nematodes, live in soil. The diversity of these animals is necessary to sustain key functions of the agro-ecosystem. Earthworms have been long recognized to have the capability of converting poor soil into rich soil. The accumulation of solid wastes is an uphill task, the management of which can be done by enhancing the scope of vermitechnology. Earthworms can be cultured and later put to various uses, i.e., to improve soil fertility, to convert organic waste into manure, to produce protein-rich food for livestock, drug and vitamin source as natural detoxicant, and a bait for fish (Ghosh 2004).

For these purposes, the most commonly cultured species of earthworm worldwide is *Eisenia fetida*, also known as the Tiger or Brandling worm (Haimi 1990). Other suitable species include *Lumbricus rubelles*, *Eudrilus eugeniae* and *Perionyx excavatus* (Edwards 1995). *Eudrilus eugeniae* is used extensively for bio-composting in the tropics, especially Africa and Asia, and is capable of bioconversion of large quantities of organic waste (Sinha *et al.* 2002).

Before recommending the use of any species on a commercial level, it is imperative that the reproductive biology and the growth of the species be worked out. The present study was designed to compare the life cycle of *Eudrilus eugeniae* with the reference species *Eisenia fetida*, under laboratory conditions using farm yard manure as a substrate.

To study the reproduction and growth of *Eisenia fetida* and *Eudrilus eugeniae*, five non-clitellated hatchlings of both species, weighing 500-550 mg were observed. Each was introduced separately in rectangular plastic containers (18.5 x 13.5 cm) containing 200 gm of farm yard manure (FYM). These were placed in triplicate at room temperature and continually monitored for mortality, sexual maturity and cocoon production. The moisture content of substrate was maintained at about 80%. Duration of life cycle, incubation time (in days) for cocoons to hatch and the number of hatchlings from one cocoon were the reproductive parameters recorded (Table 1). The mean values were calculated from the triplicate sets. The substrate in the container was turned out, earthworms were separated by hand, after which they were examined for clitellum development. They were weighed after drying on tissue paper. All earthworms and substrate were then returned to the respective containers. No additional feed was added at any stage during the study period. Cocoon production was recorded weekly. After the earthworms laid cocoons, the cocoons were separated from each dish by hand. Freshly laid cocoons were kept separately in Petri dishes (8.6 x 8.6 cm) with substrate and observed every three days to record hatching. The cocoons were kept in the same substrate in which their parents had grown as followed by Dominguez *et al.* (2001). These cocoons were further used for studying different life stages of *E. fetida* and *E. eugeniae*. Mean number of hatchlings were recorded in each plate.

Results

Growth rate – The mean weight of five earthworms of *Eudrilus eugeniae* was 7.489 ±0.07 gm, which was significantly ($P<0.05$) higher than mean weight of 3.926 ±0.04 gm attained by *Eisenia fetida*. The maximum weight (worm^{-1}) gain of *E. eugeniae* was 141 mg per week as against 56 mg per week for *E. fetida* (Fig. 1). The growth rate has been a good comparative index to compare the growth of different earthworm species as indicated by Edwards *et al.* (1998). Maximum weight gain of about 60 mg per week in case of *E. fetida*, comparable to the present observations, has

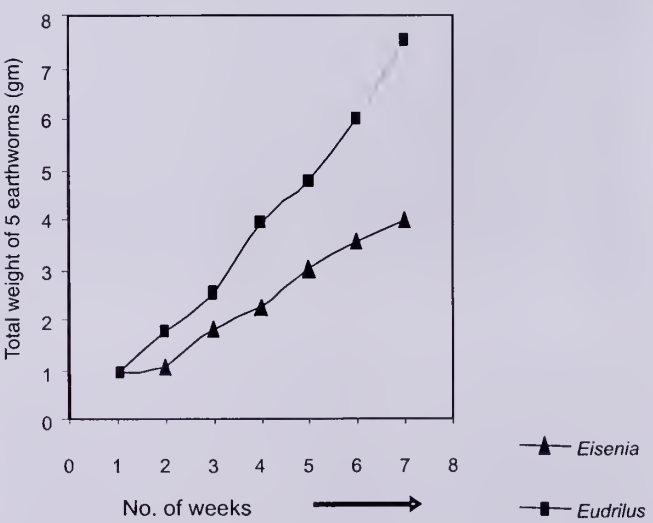

Fig. 1: Growth of *Eisenia* and *Eudrilus*

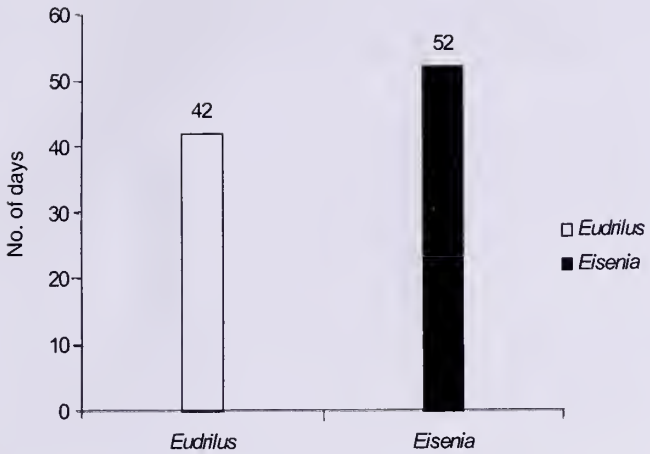

Fig. 2: Age (in days) at which worms of in FYM both species develop the clitellum. Each batch consists of five worms

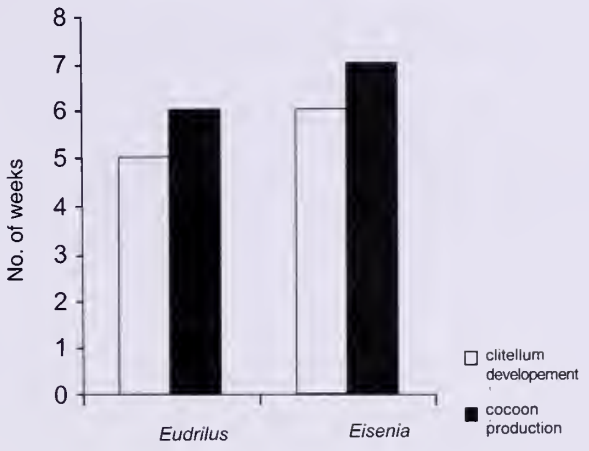

Fig. 3: Time duration of start of clitellum development and cocoon production in two species of earthworms

been reported by earlier workers (Graff 1974; Watanabe and Tsukamoto 1976). Dominguez *et al.* (2001), however, have reported a maximum weight gain per week of 280 mg, which is in contrast to the present observations. The record of increase of weight per worm per week by Reinecke *et al.* (1992) was 150 mg and comparable to our results. Chaudhari *et al.* (2004) have recorded similar comparable growth rates of 202 mg per week in *E. eugeniae* and 44 mg per week in *E. fetida* using rubber leaf litter as substrate. The results of this study corroborate the earlier findings that there is a general rule establishing a direct relationship between the growth and quality of feed material, i.e., substrate (Butt 1993; Elvira *et al.* 1997), except for local climatic differences.

Clitellum development and cocoon production – In both the epigeic species studied, clitellum development is an indication of attaining sexual maturity (Fig. 2). Clitellum developed in *E. eugeniae* in 36 days with all worms being fully clitellate by 42 days. In *E. fetida*, the first fully clitellate individual was observed after 44 days, with all the worms being fully clitellate by 52 days after hatching. Reinecke *et al.* (1992) and Dominguez *et al.* (2001) reported a duration of 35 days for attaining sexual maturity in case of *E. eugeniae* while Harteinstein *et al.* (1979) reported 42-56 days as the duration for producing cocoons in *E. fetida*. Cocoon production started after a week in both species after attaining sexual maturity. The cocoon production per worm per day for *E. fetida* was 0.47 ±0.07, and for *E. eugeniae* was 0.62 ±0.06 (Fig. 3). Cocoon production was thus higher in *E. eugeniae*. Mean cocoon production per worm per day of *E. eugeniae* was higher than 0.46 as reported by Reinecke *et al.* (1992), but lower than 1.26 as reported by Vilijoen and Reinecke (1989). Knieriemen (1985) and Dominguez *et al.* (2001) reported mean cocoon production per worm per day of 0.50 and 0.55 respectively for *E. eugeniae*. The mean cocoon production per worm per day for both species during the present investigation is shown in Fig. 4.

Incubation period and number of hatchlings from one cocoon – The mean incubation period for *E. eugeniae* was 17 ±0.82 days and 21 ±2.5 days for *E. fetida*. Reinecke *et al.* (1992) recorded incubation period of 15 days for *E. eugeniae* and 19 days for *E. fetida*. Dominguez *et al.* (2001) reported incubation period of 14 days in *E. eugeniae*. The present study reveals that, the hatchlings of *E. eugeniae* from a single cocoon ranged between one and three. Only few cocoons produced four hatchlings (Fig. 4). Vilijoen and Reinecke (1989) reported that cocoons of *E. eugeniae* can produce up to five hatchlings. The maximum number of hatchlings observed in the present study from a cocoon was

Table 1: Reproductive parameters of *Eisenia fetida* and *Eudrilus eugeniae*

S.No.	Reproductive parameters	*Eisenia fetida*	*Eudrilus eugeniae*
1.	Duration of life cycle (days)	70 ±1.24[b]	58 ±0.82[a]
2.	Cocoon production (worm^{-1}day^{-1})	0.47 ±0.07[b]	0.62 ±0.06[a]
3.	Incubation period (days)	21 ±2.5[b]	17 ±0.82[a]
4.	No. of hatchlings from one cocoon	1-5	1-3
5.	Mean number of hatchlings	3.3 ±0.94[a]	2.66 ±0.44[a]

a,b: Significant difference-t-test ($p<0.05$)
Values are mean ±SD (Triplicate set)

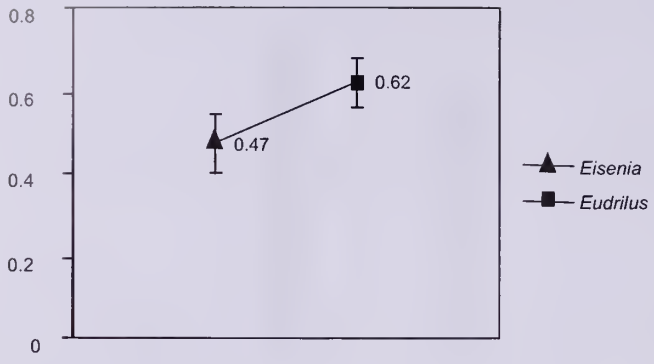

Fig.4: Mean cocoon production per worm per day in two species

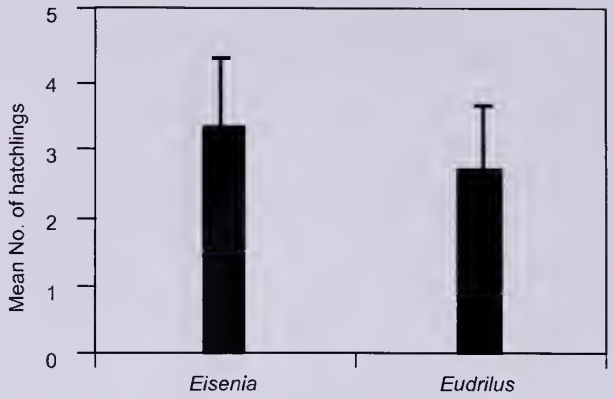

Fig. 5: Mean Number of hatchlings per cocoon in both species

up to five in *E. fetida*, which is higher than in *E. eugeniae* (Fig. 5). Evans and Guild (1948) observed 1-4 hatchlings from one cocoon in *E. fetida* while Dhiman and Battish (2005) observed emergence of two hatchlings from cocoon of *E. fetida*.

Life cycle – Life cycle duration was 58 days for *E. eugeniae* while it was 70 days for *E. fetida*, as the incubation period for *E. eugeniae* was shorter. Reinecke *et al.* (1992) observed life cycle duration of 60 and 70 days for *E. eugeniae* and *E. fetida* respectively. The present results follow a trend similar to earlier findings in different laboratories of the world. However, in direct contrast are the observations of Tripathi and Bhardwaj (2004) who have reported up to 120 days for *E. fetida* to complete its life cycle. It is probably due to the ambient climatic conditions (hot and dry in Rajasthan) where the experiment was conducted.

Conclusion

Both *Eisenia fetida* and *Eudrilus eugeniae* can survive in organic matter in the absence of soil and can be used for the conversion of organic wastes into compost. *E. eugeniae* has a shorter life cycle (58 days), higher cocoon production (0.62), shorter incubation period (17 days) than *E. fetida*. Though, *E. eugeniae* has less mean number of hatchlings from single cocoon it is well-compensated by the growth rate of 141 mg per week. The findings indicate that *E. eugeniae* has a higher reproduction potential than *E. fetida* and in favourable conditions is a faster growing earthworm.

ACKNOWLEDGEMENTS

We thank the Professor and Head, Department of Zoology, Punjab Agricultural University for providing the necessary facilities for conducting research and the Punjab Agricultural University for providing financial assistance in the form of Merit Fellowship to Zinia during the entire course of this study.

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11. *CORTIELLA CAESPITOSA* SHAN & SHEH (APIACEAE) — A NEW ENTRANT TO INDIA

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The genus *Cortiella* Norman was established by Norman (in *J. Bot.* 75: 94. 1937) with the single species *Cortiella hookeri* (C.B. Clarke) Norman based on *Cortia hookeri* C.B. Clarke, distributed in the Sikkim Himalaya, India. The genus *Cortiella* was segregated from *Cortia* DC., mainly based on the characters of rays and the morphology of fruits. Another species, *Cortiella caespitosa* Shan & Sheh (in *Acta Phytotax. Sin.* 18: 376. 1980) has been described from Xizang area of Tibet (China) and considered as endemic to China (Menglan and Watson 2005). Watson added a third species *C. cortioides* (Norman) Watson (in Edinburgh *J. Bot.* 53: 130. 1996) based on *Selinum cortioides* Norman. Presently, all the three species are known to occur in the Eastern Himalayas from Nepal, India (Sikkim), Bhutan to China (Tibet). Mukherjee and Constance (1993) in their revision of the Family Umbelliferae (Apiaceae) of India had maintained two species, *Cortiella hookeri* (C.B. Clarke) Norman and *C. cortioides* (Norman) Watson (as *Selinum cortioides* Norman).

During the floristic studies of Sikkim Himalayas I came across a few gatherings of *Cortiella* in the herbaria of Botanical Survey of India, Sikkim Himalayan Circle, Gangtok, Sikkim (BSHC), and Central National Herbarium (CAL), which had been collected from the Sikkim Himalaya, and identified as *Cortiella hookeri*. The small caespitose habit along with uni- to sub-bipinnate leaves and collar-like expanded pedicel tip clearly revealed that all these specimens are truly *Cortiella caespitosa* Shan & Sheh, but not *C. hookeri* as identified earlier. Further, the identity of the specimens was also confirmed by comparison with the protologue and the other literature as Flora of China (Menglan and Watson 2005). Thus, its presence is a new record for India from the Sikkim Himalaya.

A detailed description along with illustrations and a key to the species of *Cortiella* are presented in order to facilitate its identity.

KEY TO THE SPECIES OF *CORTIELLA* NORMAN

1. Plant smaller, less than 5 cm diam.; leaves 1- (2-) pinnate; pedicels dilated at tip, collar-like ..... *C. caespitosa*
— Plants larger, more than 7 cm diam.; leaves 2- (3-) pinnate; pedicels never dilated at tip 2
2. Ultimate leaf segments longer, more than 4 mm; wings on fruits convoluted ..... *C. cortioides*
— Ultimate leaf segments smaller, less than 4 mm; wings on fruits not convoluted ..... *C. hookeri*

Cortiella caespitosa R.H. Shan & M.L. Sheh, Acta Phytotax. Sin. 18: 376. 1980; Menglan & Watson, Fl. China 14:154.2005 (Fig. 1).

Stemless, caespitose, perennial herb, 3.5-5.0 cm in diam. *Leaves* few, rosulate, oblong in outline, 1.5-2.5 cm long, uni- to sub-bipinnate; leaflets to 5 mm long; ultimate segments obovate-elliptic or linear, *c.* 2x1 mm, simple or 2- (3-) lobed, thick, glabrous; petioles sheathing at base, sparsely puberulous. *Inflorescence* a compound umbel; umbellule several (*c.* 10), crowded, unequal to equal, 0.5-1.5 cm long, glabrous, *c.* 10-flowered; bracteoles simple, linear-oblong (-elliptic), *c.* 3-4x0.5-1 mm, puberulous along margin. *Flowers* bluish-green, white- or purple-tinged; pedicels 2-5 mm long, dilated above, glabrous; receptacle annular; petals subequal, obovate-elliptic, *c.* 1.5x0.8 mm, apex strongly inflexed, apiculate; midvein thinly winged, purplish; stamens subequal, *c.* 2 mm long; filaments 1.2-1.5 mm long, often with a constriction towards apex, vein lateral; ovary oblongoid-obovoid, *c.* 1.5x1 mm, winged; wings unequal, thin; styles

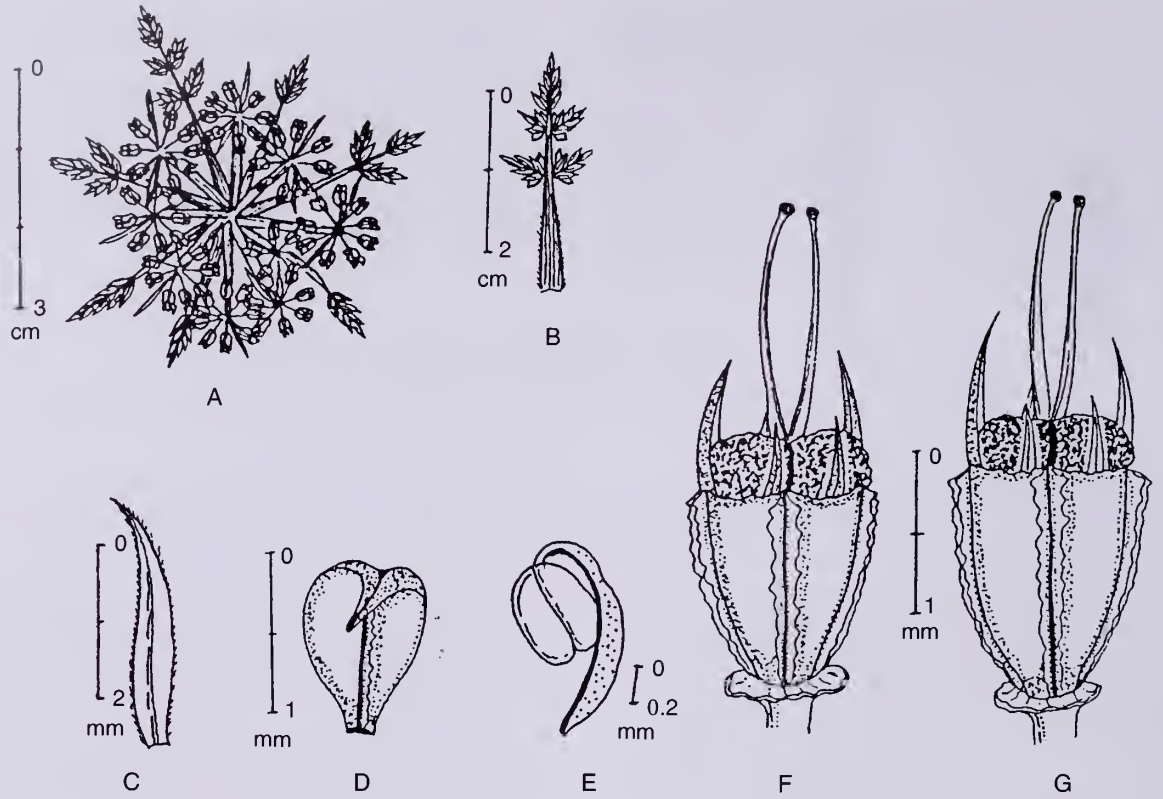

Fig.1: *Cortiella caespitosa*: A – Habit with inflorescence; B – Leaf; C – Bracteole; D – Petal; E – Stamen; F – Ovary with annular receptacle; G – Fruit (immature) with persistent sepals and styles

c. 1.5 mm long, subequal. *Fruits* immature, oblongoid-obovoid, *ca* 1.7x1 mm, dorsally compressed; ridges winged.

Flowering & Fruiting: June-October.

Grows on gravelly slopes in open alpine grassy meadows; 4,500-5,200 m.

Distribution: India (Sikkim), Bhutan (?); China (Tibet).

Specimens Examined: INDIA: Sikkim, North district, Teesta-Khangsee-Khungrona La, 6 Aug. 1987, *Singh* 8155; Dorjee La, 7 Aug. 1987, *Singh* 8185 (all at BSHC); Nattong, July 12, 1877, *King* 4347; Without any precise locality, *s.d., Cave* 306; TIBET: without any precise locality (probably Chumbi), 1882, *King's collector* 116, acc. nos.189820/21 (all at CAL).

ACKNOWLEDGEMENTS

I am thankful to the Joint Director, Botanical Survey of India, Sikkim Himalayan Circle, Gangtok and the Additional Director, Central National Herbarium (CAL), Botanical Survey of India, Kolkata, for giving permission to consult herbaria and the library. I am also grateful to Prof. G.G. Maiti, Department of Botany, University of Kalyani, West Bengal, for guidance and encouragement.

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Printed by Bro. Leo at St. Francis Industrial Training Institute, Borivli, Mumbai 400 103 and published on October 06, 2010 by Dr. Ashok Kothari for Bombay Natural History Society, Hornbill House, Dr. Sálim Ali Chowk, Shaheed Bhagat Singh Road, Mumbai 400 001, Maharashtra, India.

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Printed by Bro. Leo at St. Francis Industrial Training Institute, Borivli, Mumbai 400 103 and published by Dr. Ashok Kothari for Bombay Natural History Society, Hornbill House, Dr. Sálim Ali Chowk, Shaheed Bhagat Singh Road, Mumbai 400 001.
website: www.bnhs.org; Email: bnhs@bom4.vsnl.net.in